

The Millimeter- and Submillimeter-Wave Spectrum of *Gauche-Ethyl*
Alcohol

J. C. PEARSON*, K. V. L. N. SASTRY**, ERIC HERBST^{†,***}
AND FRANK C. DE LUCIA[‡]

**Jet Propulsion Laboratory, California Institute of Technology,*
Mail Stop 183-301, 4800 Oak Grove Dr., Pasadena, CA 91109-8099

** *Department of Physics, University of New Brunswick*
Fredericton, New Brunswick, E3B 5A3 Canada

[†] *Department of Physics, The Ohio State University, Columbus, 01143210-1106*

^{***} *Department of Astronomy, The Ohio State University, Columbus, 01143210-1106*

Number of Pages: 57

Number of Figures: 6

Number of Tables: 4

Running Head: SPECTRUM OF GAUCHE - ETHYL ALCOHOL

Send Correspondence to: Eric Herbst

Department of Physics
The Ohio State University
174 W. 18th Ave.
Columbus, OH 43210

ABSTRACT

We report an investigation of the rotational-torsional spectrum of the *gauche* rotational isomers of ethyl alcohol in the 51 -505 GHz frequency region. Over a thousand transitions between rotational levels in the *gauche* substates of the ground OH torsional state have been measured and assigned. These transitions involve rotational quantum numbers J and K_a up to 30 and 15, respectively, and are of two types: a-type transitions between levels in either the *gauche*⁺ or the *gauche*- sub state, and c-type transitions between rotational levels in the different substates. The majority of these transitions have been fit satisfactorily using a two-state Hamiltonian based on the fixed framework axis method (FFAM). The rotation, distortion, and interaction constants have been determined along with the energy difference between the two *gauche* substates. The derived constants can be used to predict many more transitions accurately for astronomical purposes. The J and K_a region where the two-state analysis can be used has been determined. The basis for a three-state analysis including the *trans* substate is presented and the applicability of the FFAM approach is discussed,

I. INTRODUCTION

The microwave spectrum of ethyl alcohol (ethanol, $\text{CH}_3\text{CH}_2\text{OH}$) has been the subject of many previous investigations with the majority of the work being done on the more stable *trans* rotational isomer, or rotamer. This work has been reviewed in our previous study of the millimeter- and submillimeter-wave spectrum of Irons -ethyl alcohol (1). In this previous work, we were able to fit a large number of transitions occurring in the *trans* substate of the ground OH torsional state to microwave accuracy with a single-state Watson-type Hamiltonian by averaging the small splittings caused by the methyl internal rotation. Kakar and Seibt (2) and Kakar and Quade (3) first studied rotational-torsional spectra involving the gauche substates (*gauche+* and *gauche-*) of the lowest OH torsional state, which lie approximately 40 cm^{-1} above the *trans* substate, and determined the potential barriers to OH torsional and methyl mot ions, as well as the *gauche* dipole moment components. Our previous work on the *trans* rotamer (1) and earlier work of Michielsen-Effinger (4) revealed a large number of transitions that could not be analyzed using a single-state Watson Hamiltonian. The level shifts are now known to be the result of interactions with rotational levels of the *gauche* states at higher rotational quantum numbers than had previously been studied.

Ethyl alcohol in the ground *trans* substate of the OH torsion has been observed in several warm, dense interstellar molecular clouds, following its initial observation by Zuckerman *et al.* in Sgr 132 (5,6). The molecule appears to be localized in regions known as Hot Cores, which are relatively warm and dense regions with gas densities of 10^6 - 10^8 cm^{-3} and temperatures of 100-300 K located near star formation activity. As a result of our recent laboratory work, a large number of millimeter-wave ethyl alcohol transitions have been detected in the Hot Core (334.3+0.15 and analyzed to show that ethanol is a major molecule in the source (7). It is presumed that ethanol or a suitable precursor is formed on the surfaces of dust particles during a previous colder era before star formation has started;

the onset of star formation heats up the region and results in the evaporation of material from the dust particle surfaces (8). All of the confirmed astronomical observations to date are of the *trans* isomer; however, it should be possible to detect transitions in the *gauche* substates as well since they lie ≥ 60 K above the lowest *trans* substate. In addition, the significant energy difference between the *trans* and *gauche* substates may prove to be a useful probe of temperature in star forming regions.

This work, a study of rotational-torsional transitions in the lowest-lying *gauche* substates, is the second part of a study of the millimeter- and submillimeter-wave spectrum of the ground vibrational state of ethyl alcohol. One purpose of this paper is to provide an analysis of the *gauche* substates in the low J and K_a region where interactions with the *trans* substate are negligible; such an analysis leads to accurate frequency predictions for many unstudied transitions, as is needed for astronomical assignments. Another purpose is to test the applicability of the fixed-framework axis method (FFAM) for moderately high J and K_a values for the case of a molecule with an intermediate barrier against torsional motion. Yet a third purpose is to explore the range and kinds of interactions between the *trans* and *gauche* substates, in preparation for a full three-state analysis, which we plan in the future.

II. THEORY

Ethanol is a near-prolate asymmetric top with two internal motions: the threefold symmetric internal rotation of the methyl protons and the asymmetric internal rotation of the hydroxyl proton. The potential energy for each internal rotation can be expanded in a trigonometric series with terms $1 - \cos(n\gamma)$, where γ is a torsional angle, and coefficients $V_{3n}^{\text{meth}}/2$ for the methyl case and $V_n^{\text{OH}}/2$ for the hydroxyl case. The threefold symmetry of the methyl group leads to torsional substates of A and E symmetry in the C_3 group with selection rules A-A and E-E. Since the threefold methyl barrier V_3^{meth} (1173.7 cm^{-1} and 1331 cm^{-1} in the lowest *trans* and *gauche* substates, respectively) is large (1,3), rotational

transitions within these substates occur at closely spaced pairs of frequencies. In the *trans* state, many A-E splittings have been resolved and analyzed (1,9) but no methyl splittings of the *gauche* states were resolved by this work.

The potential for the internal rotation of the hydroxyl proton, depicted in Figure 1, has been characterized by the three potential coefficients $V_1^{\text{OH}} = 57.0 \text{ cm}^{-1}$, $V_2^{\text{OH}} = 0.8 \text{ cm}^{-1}$ and $V_3^{\text{OH}} = 395.0 \text{ cm}^{-1}$ (3). The global minimum is referred to as the *trans* configuration or rotamer; in this configuration the hydroxyl proton is perfectly staggered between the protons on the methylene group and the methyl group (1). Two secondary minima, referred to as *gauche* configurations or rotamers, occur at torsional angles of -120° from the *trans* configuration. Solution of the torsional wave equation shows that the ground hydroxyl torsional state splits into three substates with an increasing degree of localization as the barrier height increases: a *trans* or e_0 substate with a wave function of A' symmetry (C_s group) that peaks at the global potential minimum and two closely-spaced *gauche* substates, which are degenerate in the threefold case and lie above the *trans* substate in the lowest torsional state. The *gauche* substates are characterized by symmetric (*gauche*+ or e_1 , A') and anti-symmetric (*gauche*- or o_1 , A'') wave functions with the *gauche*+ substate the lower in energy. With the above potential, the *gauche*+ and *gauche*- substates of the ground torsional state are split by 3.2 cm⁻¹, and the *gauche*+ substate lies 41.2 above the *trans* substage. Figure 2 shows computed torsional wave functions for the *trans*, *gauche*+, and *gauche*- substates. These wave functions are very similar to those for CH₂DOH and CHD₂OH (10,11), with the ethanol wave functions being a bit more localized. Figure 3 shows how a ground vibrational state rotational level is split by the hydroxyl and methyl torsional motions. The energy differences among the substates in Figure 3 are from this work and are discussed later.

The *trans* substate of ethyl alcohol has a dipole moment that lies almost exactly on the b principal axis ($\mu_b = 1.46 \text{ D}$); the c- component is zero by symmetry, and the a- component μ_a is estimated to be 0.046 D (12). The *gauche* substates, on the other

hand, have a large dipole moment along the a principal axis ($\mu_a = 1.264$ D), a nearly zero dipole component in the b-direction ($\mu_b \approx 0.104$ D), and a substantial component in the c-direction ($\mu_c \approx 1.101$ D) (3). Considering the sizes of the dipole components and the symmetry of their dependence on torsional angle in the C_s group, it is easily seen that strong rotational transitions within the *gauche*⁺ or *gauche*- substates have a-type selection rules (weak b-type transitions are also possible), whereas torsional transitions between *gauche*⁺ and *gauche*- states have c-type selection rules (3). The latter transitions determine the separation between the two *gauche* substates and the K_a -dependent spectroscopic constants. From the symmetry, transitions between *trans* and *gauche*⁺ substates are expected to occur with a-type and b-type selection rules while transitions between *trans* and *gauche*- substates are expected to be c-type. Analogous *trans* to *gauche* transitions have been reported for CH₂DOH and CHI₂OH (10,11) but maybe much weaker in ethanol due to the higher degree of localization of the wave functions and the very different dipole directions in the *trans* and *gauche* substates. The one exception is in the event of mixings between near degenerate rotational-torsional levels belonging to different torsional substates. Transitions between the *trans* and *gauche* substates will precisely determine the excitation energy of the latter substates. In the absence of such reported transitions, Kaker and Quade determined that the *gauche*⁺ substate lies 41.2 ± 5.0 cm⁻¹ above the *trans* substate from intensity measurements (3). Our observations of the location of perturbations between the *trans* and *gauche* levels suggest that the *trans-gauche*⁺ energy difference is 39.2 cm⁻¹.

The energy difference between *trans* and *gauche* states is large enough to leave a significant number of *trans* and *gauche* rotational levels unaffected by each other, but the larger rotational constants for the *trans* rotamer result in significant level crossings at high J and K_a values, with pairs of levels interacting via symmetry-allowed torsional interactions on- and off-diagonal in K_a . The net result is that rotational transitions in the different rotamers should be unperturbed for a fairly wide range of low J and K_a values, but at

higher J and K_a values many *trans* rotamer rotational energy levels will cross the *gauche* rotamer energy levels with the same J quantum numbers; resulting in the Coriolis-like perturbations that are observed in the spectrum. The small 3.2. cm⁻¹ energy difference between the *gauche* substates and matrix elements between these substates on- and off-diagonal in K_a result in strong perturbations beginning at low J values, requiring interactions between the *gauche+* and *gauche-* substates to be considered in any analysis of the *gauche* spectrum (3).

A Hamiltonian for the asymmetric top-asymmetric frame internal rotation problem was proposed and demonstrated by Quade and co-workers (1316). The Hamiltonian H can be divided into three parts (13):

$$\mathbf{H} = \mathbf{H}_R + \mathbf{H}_{TR} + \mathbf{H}_T \quad (1)$$

where \mathbf{H}_R is the quasi-rigid-body rotational Hamiltonian, \mathbf{H}_T is the torsional Hamiltonian, and \mathbf{H}_{TR} is the torsional-rotational interaction. In this formulation, \mathbf{H}_{TR} has significant contributions both on and off diagonal in torsional state as well as substate σ , where $\sigma = t$, +, and - for *trans*, *gauche+*, and *gauche-*, respectively. For implementation of the Hamiltonian, the portion of \mathbf{H}_{TR} diagonal in torsional substate is folded into \mathbf{H}_R . The torsional Hamiltonian is not solved directly; rather, the splitting between the $\sigma = +$ and - torsional sublevels of the ground torsional state is treated as a parameter to be determined from the spectra. Van Vleck perturbation theory is used to fold in the contributions of excited torsional states to \mathbf{H}_{TR} (as in the PAM approach to threefold symmetric internal rotors - see reference (17)). These steps result in the following effective Hamiltonian H to second order in the angular momentum:

$$\begin{aligned} H_R &= A^{(\sigma)} P_a^2 + B^{(\sigma)} P_b^2 + C^{(\sigma)} P_c^2 + F^{(\sigma)} (P_a P_b + P_b P_a) \\ H_{TR} &= D^{(\sigma^1, \sigma^2)} (P_b P_c + P_c P_b) + E^{(\sigma^1, \sigma^2)} (P_c P_a + P_a P_c) + F^{(\sigma^1, \sigma^2)} (P_a P_b + P_b P_a) + \end{aligned}$$

$$M^{(\sigma^1, \sigma^2)} P_c + N^{(\sigma^1, \sigma^2)} P_b \bullet Q^{(\sigma^1, \sigma^2)} P_a \\ H_T = \Delta E(\sigma) . \quad (2)$$

This type of effective Hamiltonian has been applied in various forms by Quade and co-workers (18-21) and Hirota and co-workers (22-24), and is referred to as the fixed framework axis method (FFAM). An internal axis method (IAM) alternative to this approach has been described by Quade and co-workers (10-11; 25-27). In the FFAM formulation, all the H_{TR} terms are between different torsional substates, with $\sigma^1 \neq \sigma^2$. We have neglected terms that contain the torsional dependence of the rotational constants; however, the H_{TR} terms were expanded to higher order in P^2 and P_a^2 operators to account for some of the rotational-torsional interaction. The $P_a P_b + P_b P_a$ terms in H_R define a rotation of the a and b axes from the principal axis system. This term can be set to zero in any one substate fixing the axis system for the problem. In the analysis described below, this was done for the *gauche+* substate. Although the K dependence of the torsional problem has been limited to H_{TR} , there are higher order corrections which can be formulated in terms of a K-dependent ΔE .

The H_{TR} term in the effective Hamiltonian contains (oriolis-type interactions which are not small. The expansions in these terms do not necessarily converge rapidly and higher order terms are necessary in our analysis. The non-zero H_{TR} matrix elements connecting the different torsional substates of ethanol can be easily ascertained using the C_s symmetry group, taking advantage of the fact that the torsional and rotational operator factors of each term must transform similarly so that the overall operator is symmetric. The ‘ah’ plane is the plane of symmetry (σ_h) containing the three heavy atoms, so that the angular momentum operators P_a and P_b transform according to the antisymmetric representation A“ whereas P_c transforms according to A’. Thus, the symmetric torsional states (*trans*, *gauche+*) will be connected by terms in H_{TR} containing the symmetric angular momentum terms P_C and $P_a P_b + P_b P_a$, whereas symmetric-antisymmetric

combinations (*gauche*⁺-*gauche*⁻; *tram-gauche*⁻) will be connected by terms in H_{TR} containing the antisymmetric angular momentum terms P_a , P_b , $P_a P_c + P_c P_a$ and $P_b P_c + P_c P_b$. The symmetry-allowed Hamiltonian elements to second order in angular momentum are shown in Figure 4. In addition to these matrix elements, it is also possible that *trans* and *gauche*⁺ states of the same overall symmetry can be connected by additional terms in H_{TR} containing torsional dependence of the rotational constants symmetric in torsional angle. The angular momentum terms are evaluated in the normal prolate symmetric top IR representation. The $\sim 40 \text{ cm}^{-1}$ energy difference between *trans* and *gauche*⁺ substates is sufficient to justify effectively separating the Hamiltonian into separate *trans* and *gauche* sub-blocks for a large number of J and K_a values, an assumption made in our previous *trans* state analysis (1) and the two-state, *gauche*⁺-*gauche*⁻ analysis presented here.

In addition to the 2×2 effective Hamiltonian above, we have included diagonal fourth and sixth order centrifugal distortion terms in the s-reduction approach (17) as well as the (symmetrized) higher-order H_{TR} terms: $P_a P^2 (Q_J^{+-})$, $P_b P^2 (N_J^{+-})$, $P_a P_a^2 (Q_K^{+-})$, $P_b P_a^2 (N_K^{+-})$, $P_b P_a^4 (N_{KK}^{+-})$, $P_a P^4 (Q_J J^{+-})$, $P_b P^4 (N_J J^{+-})$, $P_a P^2 P_b^2 (Q_{JK}^{+-})$ and $P_b P^2 P_a^2 (N_{JK}^{+-})$ with the spectroscopic constants shown in parentheses.

111. EXPERIMENTAL

Reagent grade ethanol obtained from commercial sources was introduced into sample cells ranging from one to four meters in length. Measurements were made at pressures from 6 to 60 mTorr. The weaker transitions were observed at higher pressures and with larger modulation. The spectra were recorded on five different spectrometer systems. Gauche a-type R branches between 78 and 117 GHz were measured at the Physikalisch-Chemisches Institute of the Justus Liebig Universität in Giessen, Germany on a spectrometer which uses a KVA RZ millimeter-wave synthesizer as a source. The lines near 50 GHz were recorded with a phase locked klystron at the University of New

Brunswick, Spectra through 360 GHz were recorded at The ohio State University with two sources: either a tripled YIG oscillator amplified by a TWT amplifier and multiplied by a Gordy type harmonic generator, or a 55 GHz klystron and a similar harmonic generator. Spectra through 505 GHz were recorded at the Jet Propulsion Laboratory with a 100 GHz klystron source and harmonic generator. InSb hot electron bolometers were used in second derivative detection in most cases. Some of the low frequency lines were recorded with diode detectors. The details of these spectrometer systems can be found elsewhere (28-31). The measurement accuracy is estimated to be better than 100 kHz for all transitions measured in this work.

More than a thousand *gauche* transitions have been measured and the majority of them have been successfully analyzed. These transitions include very strong *gauche*+ and *gauche*- a-type R branches and many strong *gauche*+ to *gauche*- c-type Q and R branches, along with some weaker c-type P branches. No methyl internal rotation splitting was resolved, but some of the lower frequency c-type transitions did appear to have unresolved structure. Since the splittings were not resolved, no attempt at a methyl internal rotation analysis was made and all spectra reported are effectively averaged over any methyl splittings.

Many new transitions in the *trans* substate were measured and assigned, including some exhibiting perturbations. None of the *trans* transitions inside the J and K_a ranges previously reported and analyzed (*I*) shows any deviation from predictions. As a result, these transitions will not be presented here. A large number of *gauche* transitions exhibiting perturbations with the *trans* sub state were also observed but most are not included in the present analysis, since they require a three-state treatment of the hydroxyl torsional motion. An attempt is currently underway using the full three-state Hamiltonian to analyze all the *gauche* and *trans* transition observed; however, no completely satisfactory results have been obtained so far. In addition to the assignment of the *gauche* rotational spectrum including higher J quantum numbers and frequencies than studied previously,

this work has determined the range of J and K_a values for which the *gauche* substates can be analyzed without considering interactions with the *trans* substate.

IV. ANALYSIS

The Hamiltonian described in Section II was fit to over 1000 rotational-torsional transition frequencies in the *gauche* substates involving rotational quantum numbers J and K_a through 30 and 15, respectively. The fit was accomplished using the linear least squares refinement program available from the on-line Jet Propulsion Laboratory spectral catalog at spec.jpl.nasa.gov (32,33). The root-mean-square (RMS) deviation of the fit, 391 kHz, was obtained by varying 45 spectroscopic parameters. The RMS deviation obtained significantly exceeds the experimental accuracy of the measured frequencies, although most lines are fit to the accuracy of the experiment. The overwhelming majority of the more poorly fit transitions have been confirmed via both loop and error curve techniques. Many of these transitions show systematic deviations; the origins of most of the deviations can probably be explained by *trans-gauche* interactions.

The determination of the off-diagonal P_a and P_b terms and their distortion expansions was very difficult since these terms are highly correlated with the Coriolis $P_a P_c + P_c P_a$ and $P_b P_c + P_c P_b$ terms as well as the rotations] constants and distortion constants. The P_a and P_b terms off diagonal in torsional substate were successfully determined only after transitions on both sides of the *gauche-* $K_a = 0$ and *gauche+* $K_a = 1$ level crossing at $J = 13$ were included in the analysis. The on-diagonal $P_a P_b + P_b P_a$ term for the *gauche-* substate was included because it improves the analysis slightly, especially at higher K_a values, even though it reduces the overall RMS by less than 100 kHz. In similar molecules, fixing this term to zero for both gauche states is justifiable since the two gauche states should have almost exactly the same axis system (2?). The $P_a P_b + P_b P_a$ term for the *gauche+* substate was fixed to zero, defining the axis system for this state as the principal axes. The ΔE^+ term was also fixed to zero, defining the lowest energy state in

this analysis. The value of the $P_aP_b + P_bP_a$ term for the gauche- substate is somewhat larger than expected, probably the result of its accounting for tran.-gauche interactions affecting the two gauche states differently. The overall analysis presented, with an RMS of 391 kHz, was chosen because it successfully fits the most levels and comes the closest on the majority of the perturbed ones. A much lower RM S (under 200 kHz) can easily be achieved by selectively reducing the data set, however, this RMS reduction results in significantly poorer predictive power.

The measured and analyzed transitions are given in Table I. Table I includes the rotational quantum numbers, the torsional substate with 0 and 1 representing *gauche+* and *gauche-*, respectively, the residuals (observed - calculated frequencies) and any reference or notes applicable. Predictions for many unmeasured *gauche* substate transitions along with rotational energy levels and calculated line strengths are available on-line electronically from the Jet Propulsion Laboratory spectral line catalog. Table 11 contains a number of transitions with secure assignments that show slight perturbations (≤ 15 MHz) and cannot be fit with the present two-state Hamiltonian. Included in our present analysis area number of successfully fitted transitions which come from highly mixed *gauche+* and *gauche-* levels where the strong $\Delta K_a = 1$ Coriolis perturbation between the two states has shifted the levels many GHz. The dominant state assigned to these levels can change with small changes in the constants and may be reassigned once interactions with the *trans* state are considered. These levels are denoted with an asterisk in the reference column of Table I. The calculated intensities of these transitions are in reasonably good agreement with observations.

Table 111 contains the determined constants; here the superscripts +, -, and +- are used to represent the *gauche+*, *gauche-* substates and their interaction terms, respectively. Because of the large correlations (0.99) among the Coriolis constants, and because of the effective nature of the Hamiltonian used, it is hard to draw too many physical conclusions from the constants determined from the analysis. One salient feature, however, is the

similarity between the A, B and C rotational constants of the *gauche*⁺ and *gauche*⁻ states. On the other hand, the distortion constants are very similar for the perturbation expansions in J but are different in the K expansions. This difference is believed to be largely due to the onset of perturbations with the *trans* state which shift different K values within the two *gauche* states differently, but it may also be partly due to higher order contributions from the torsion. The large value of the off-diagonal Q⁺ parameter (-4 GHz), which multiplies the P_a term, results in mixing between rotational levels of the two *gauche* substates even when the energy difference between the levels is relatively large.

The values for the constants determined by this work can be compared with those of Kakar and Quade (3) in several cases. The B and C values along with the coefficients of $P_b P_a + P_a P_b$, and $P_b P_c + P_c P_b$ are in excellent agreement considering distortion constants were not used in the original work. Our energy difference between the two substates of 96748.8147 (0.0069) MHz compares reasonably well with the 96739.27 MHz value previously reported. The energy difference and the A value difference are due primarily to our inclusion of the large off diagonal P_a term in our analysis,

The analysis presented here reproduces the frequencies of a-type R branches and low K_a c-type transitions with small residuals. In particular, the a-type R branch transitions with quantum numbers below $K_a = 10$ and $J = 15$ and the c-type branches below $K_a = 6$ and $J = 15$ have been fit to microwave accuracy. In addition, the analysis was the best of all those tried for reproducing the frequencies of unmeasured c-type transitions with K_a values of 6 or more; however, none of the two-state analyses tried has been able to fit c-type transitions with $K_a \geq 9$. The high K_a problem is very similar to the high K_a ($K_a \geq 11$) problem in the *trans* state and is partly if not entirely the result of strong K_a dependent interactions between the *gauche* and *trans* substates. The origins of this problem are discussed in the next section.

V. DISCUSSION

The *gauche* state analysis presented in this paper is successful for a large number of transitions. Like the previous *trans* analysis (*I*), it does not account for all of the observed transitions, but it is sufficient to generate good spectroscopic constants for a large number of transition frequencies and intensities. Table IV gives the approximate maximum J value (J_{\max}) for each value of K_a where the *gauche* substates have been effectively analyzed. In general, the higher the value of K_a , the lower the value of J_{\max} . The J_{\max} values in the *gauche* states are generally less than in the *trans* state because the interactions affecting the levels occur with higher K_a *trans* levels. Presumably at J values sufficiently higher than J_{\max} the perturbative interactions are reduced since individual perturbations affecting two series of rotational energy levels, each characterized by K_a and α , typically increase with increasing J, go through a so-called resonance when the unperturbed series of energy levels cross each other, and then decrease once again. To understand these perturbations better requires knowledge of the positions of rotational-torsional energy levels in both the *trans* and *gauche* substates, since the majority of perturbations vitiating the two-state analysis are between these two substates.

The present analysis combined with the previous *trans* state analysis (*I*) and the *trans-gauche* + energy difference estimated from the location of known perturbations has allowed us to produce an energy level diagram for the rotational-torsional states through $J = 40$ of the ground vibrational state of ethanol. This diagram is shown through $J = 30$ in Figure 5, in which the individual state energies are marked on a plot of energy (cm^{-1}) vs J; entries in each column correspond to specific values of K_a with the symbols +, o, x designating *trans*, *gauche* +, and *gauche*- substates, respectively. The estimated energy difference between the *trans* and *gauche* + substates, 39.2 cm^{-1} , determines which levels are expected to be perturbed; in all cases checked, the transitions involving these levels are shifted from their expected position, many so badly that no assignments could be made. The energy difference will be better determined once *trans* to *gauche* transitions are observed.

Figure 5 was produced without considering any interactions between the *trans* and *gauche* states or interactions with any excited states. Nevertheless, it clearly shows the general overlap of the *trans* and *gauche* energy levels starting at intermediate J and K_a where there is more opportunity for interactions between the many *trans* and *gauche* levels. At still higher K_a values, the levels become more widely spaced but the perturbations tend to become much stronger resulting in some dramatic interactions which have been characterized and used in estimating the *trans-gauche* energy separation, although they are not included in our two-state analysis.

Two series of strong $\Delta K_a = 2$ interactions between the *trans* $K_a = 11$ levels and the *gauche*+ $K_a = 9$ levels and between the *trans* $K_a = 12$ levels and the *gauche-* $K_a = 10$ levels stand out particularly. These interactions affect all the c-type *gauche* spectra involving these levels and begin to seriously affect the a-type R branch *gauche* spectra at $J = 15$; the latter perturbations become progressively worse until $J = 25$ where the levels become so highly perturbed that they cannot be located. The unperturbed energy levels for these four series of levels are shown on Figure 6, where it can be seen that the series cross each other only gradually as a function of J . It should be noted that these resonances, caused by avoided level crossings, have different origins. The *trans* $K_a = 12$ and *gauche-* $K_a = 10$ interaction derives from a Coriolis term predicted by the matrix elements in Table 4 while the *trans* $K_a = 11$ *gauche*+ $K_a = 9$ interaction is not predicted. The *trans-gauche*+ interaction is probably the result of the torsional dependence of the rotational constants which will result in matrix elements connecting states of the same overall symmetry. In this case, the connecting matrix elements will contain a rotational asymmetry expression like $P_b^2 - P_c^2$ multiplied by the torsional dependence (e.g. $\cos(n\gamma)$).

There are many other level crossings contained in Figure 5 involving *trans* and *gauche* levels which differ in K_a by as little as one or as many as 6. The magnitudes of the interactions leading to avoided crossings are not known since very few of the more highly perturbed transitions have been assigned. In addition, since asymmetry effects mix

symmetric top levels of differing K_a , interactions with differing values of ΔK_a are correlated through the asymmetry making a complete analysis a difficult task requiring the observation of many highly perturbed transitions. Much of the non-systematic RMS deviation in the present fit can be attributed to smaller effects of the other *trans* and *gauche* perturbations.

The intensities generated by the determined constants are consistent with the vast majority of the observations. We estimate the overall accuracy of intensities tabulated from the constants to be within $\approx 10\%$, but some isolated cases are very different. Most of the problems are the result of *gauche-trans* interactions, but the true value of the *gauche* c-type dipole is somewhat suspect because the *gauche*-*trans* mixing due to the large P_a term in H_{TR} was not included in the original dipole analysis. Another source of uncertainty in the intensity calculations derives from the effects of the two torsions and their interactions. It is known, for example, that the three-fold methyl internal rotation can mix $|K>$ and $|-K>$ E states in the *trans* substate (1,28), but the effects of this type of mixing on the *gauche* substate intensities are not obvious,

VI. SUMMARY

The analysis presented here provides the constants necessary to generate the frequencies, intensities, and energy levels necessary for astronomical assignments of the *gauche* substates of ethyl alcohol. It also provides confirmation that the intermediate barrier asymmetric top-asymmetric frame internal rotation problem can be analyzed to some relatively high degree of success using the FFAM approach. The analysis of the *gauche* substates coupled with the previous analysis of the *trans* substate may provide the basis for further investigations leading to a complete treatment of the ground state of ethanol. It is quite possible that a three-state extension of our current two-state approach using a similar Hamiltonian extended to higher order will account for all of rotational-torsional transitions in the ground state of ethanol. However, previous F) AM perturbative approaches have

foundered, especially at higher K_a ($K_a > 3$) values (10,)1). The high degree of correlation in the two-state analysis presented here and the multitude of correlation possibilities among the *trans-gauche* interactions suggest that correlations will pose a major problem with the FFAM method. An asymmetric top-asymmetric frame non-perturbative internal axis method (1AM) has been proposal and applied to CH_2DOH and CHD_2OH by Quade and coworkers (10,11, 2S-27), but it has yet to be tested at sufficiently high J and K_a values for higher order effects to become important. It is highly likely that the IAM formulation or a similar type of treatment based on a suitably advantageous choice of rotated or transformed axis (34-36) will be necessary for a generally successful complete ethanol ground state analysis. A potential problem with either approach to ethanol lies in the interactions between the methyl and the hydroxyl internal motions. These interactions, especially in excited states of these motions, could seriously complicate any future analysis,

aboratory, California
institute of Technology, was done under contract with the National Aeronautics and Space Administration. We thank NASA for their support for laboratory astrophysics at The Ohio State University and the Ohio Super-computer Center for the award of time on their Cray YMP8 computer. K. V.L.N. Sastry thanks the Deutscher Akademischer Austauschdienst (DAAD) for financial support during his stay in Giessen, Germany. The laboratory work in Giessen was supported in part by the Deutsche Forschungsgemeinschaft and the Fonds der Chemischen Industrie. J. C. Pearson thanks Ed Cohen and Herb Pickett for enlightening discussions on this problem and the manuscript.

REFERENCES

1. J. C. Pearson, K. V. L. N. Sastry, M. Winnewisser, E. Herbst, and F. C. De Lucia, *J. Phys. Chem. Ref. Data* 24, 1-32 (1995).
2. R. K. Kakar and P. J. Seibt, *J. Chem. Phys.* 57, 4060-4061 (1972).
3. R. K. Kakar and C. R. Quade, *J. Chem. Phys.* 76, 4300-4307 (1980).
4. J. Michelsen-Effinger, *J. Phys.* 30, 336-340 (1969).
5. B. Zuckerman, B. E. Turner, D. R. Johnson, F. O. Clark, R. J. Lovas, N. Fourikis, P. Palmer, M. Morris, A. E. Lilley, J. A. Ball, C. A. Gottlieb, M. M. Litvak and H. Penfield, *Astrophys. J. (Letters)* 196, L99-L102 (1975).
6. T. J. Millar, H. Olafsson, A. Hjalmarson, P. D. Brown, *Astron. Astrophys.* 205, 1-5 L7 (1988).
7. T. J. Millar, G. H. Macdonald, and R. J. Habing, *Mon. Not. R. Astron. Soc.* 273, 25-29 (1995).
8. P. Caselli, T. I. Hasegawa, and E. Herbst, *Astrophys. J.* 408, 548-558 (1993).
9. R. J. Lovas, *J. Phys. Chem. Ref. Data* 11, 251-312 (1982).
10. C. F. Su and C. R. Quade, *J. Mol. Spectrosc.* 134, 290-296 (1989).
11. C. F. Su and C. R. Quade, *J. Chem. Phys.* 90, 1396-1402 (1989).
12. M. Takano, Y. Sasada, and T. Satoh, *J. Mol. Spectrosc.* 26, 157-162 (1968).
13. C. R. Quade and C. C. Lin, *J. Chem. Phys.* 38, 540-550 (1963).
14. C. R. Quade, *J. Chem. Phys.* 44, 2512-2523 (1966).
15. C. R. Quade, *J. Chem. Phys.* 47, 1073-1090 (1967).
16. J. V. Knopp and C. R. Quade, *J. Chem. Phys.* 48, 331-3324 (1968).
17. W. Gordy and R. L. Cook, "Microwave Molecular Spectra," John Wiley & Sons, New York, 1984.
18. R. E. Schmidt and C. R. Quade, *J. Chem. Phys.* 62, 3864-3874 (1975).
19. C. F. Su and C. R. Quade, *J. Chem. Phys.* 79, 5828-5834 (1983).
20. C. R. Quade and R. D. Suenram, *J. Chem. Phys.* 73, 11271131 (1980).

21. C. R. Quade, J. Chem. Phys. 48,5490-5493 (1968).
22. P. Meakin, D. O. Harris, and E. Hirota, J. Chem. Phys. 51, 3775-3788 (1969).
23. E. Hirota, J. Mol. Spectrosc. 34,516-527 (1970).
24. E. Hirota, T. Kirooka, and Y. Merino, J. Mol. Spectrosc. 26, 351-367(1968).
25. M. Liu and C. R. Quade , J. Mol. Spectrosc. 146, 238--251 (1991).
26. M. Liu and C. R. Quade, J. Mol. Spectrosc. 146,252-263 (1991).
27. C. F. Su, M. Liu and C. R. Quade, J. Mol. Spectrosc. 146, 264-273 (1991).
28. P. Helminger, J. K. Messer, and F. C. De Lucia, Appl. Phys. Lett. 42, 309-310 (1983).
29. R. I.. Booker, R. I. Crownover, and F. C. De Lucia, J. Mol. Spectrosc. **128**, 62-67 (1988).
30. W. C. King and W. Gordy, Phys Rev. 90, 319-320 (1953).
31. R. R. Friedl, M. Birk, J. J. Oh, and E. A. Cohen, J. Mol. Specctrosc. 170, 383-396 (1995).
32. R. I., Poynter and H. M. Pickett, Appl. Opt, 24, 2235-2240 (1985).
33. H. M. Pickett, J. Mol. Spectrosc. **148**, 371-377 (1991).
34. H, M. Pickett, J. Chem. Phys. S6, 1715-1723 (1972).
- 35.B. P. Van Eijck, J. Mol. Spectrosc. 82, 81-91 (1980).
36. V. Szalay, J. Mol. Spectrosc. **128**, 24-61 (1988).

TABLE 1
Measured and Analyzed *Gauche*-Ethanol Transitions

$J'K_a'K_c'TS'$	$J''K_a''K_c''TS''$	Obs.	Freq. (MHz)	Calc.	Freq. (MHz)	Obs-Calc (MHz)	Ref.
2 2 0 0 1 1 0 1		13111.570	13111.40470	0.16530	a		
2 2 1 0 1 1 1 1		14169.920	14169.92567	-0.00567	a		
4 1 4 1 4 2 2 0		15063.960	15063.93425	0.02575	a		
2 0 2 1 3 1 2 0		16249.490	16249.60808	-0.11808	a		
1 0 1 0 0 0 0 0		17288.410	17288.41869	-0.00869	a		
1 0 1 1 0 0 0 1		17295.790	17295.80281	-0.01281	a		
3 1 3 1 3 2 1 0		17557.390	17557.39203	-0.00203	a		
2 1 2 1 2 2 0 0		19302.930	19302.97203	-0.04203	a		
2 1 1 1 2 2 1 0		22618.680	22618.69650	-0.01650	a		
3 1 2 1 3 2 2 0		24288.620	24288.64765	-0.02765	a		
8 3 6 0 8 2 6 1		24383.180	24383.25101	-0.07101	a		
7 3 5 0 7 2 5 1		26148.250	26148.26179	-0.01179	a		
4 1 3 1 4 2 3 0		26501.780	26501.82200	-0.04200	a		
6 34 0 62 4 1		27359.800	27359.80950	-0.00950	a		
5 3 3 0 5 2 3 1		28120.260	28120.26976	-0.00976	a		
4 3 2 0 4 2 2 1		28543.070	28543.11029	-0.04029	a		
3 3 1 0 3 2 1 1		28737.600	28737.70665	-0.10665	a		
3 3 0 0 3 2 2 1		28912.360	28912.27072	0.08928	a		
4 3 1 0 4 2 3 1		29067.890	29067.91036	-0.02036	a		
5 1 4 1 5 2 4 0		29255.850	29255.85819	-0.00819	a		
5 3 2 0 5 2 4 1		29345.430	29345.43357	-0.00357	a		
3 2 1 0 2 1 1 1		29406.890	29406.87888	0.01112	a		
6 3 3 0 6 2 5 1		29804.560	29804.56017	-0.00017	a		
7 3 4 0 7 2 6 1		30521.600	30521.58270	0.01730	a		
8 3 5 0 8 2 7 1		31592.270	31592.24620	0.02380	a		
322 02 1 2 1		32509.180	32509.19519	-0.01519	a		
6 1 5 1 6 2 5 0		32570.910	32570.93797	-0.02797	a		
2 1 2 0 1 1 1 0		33487.510	33487.54631	--0.03631	a		
2 1 2 1 1 1 1 1	.	33508.450	33508.44119	0.00881	a		
2 0 2 0 1 0 1 0		34541.530	34541.54675	-0.01675	a		
2 0 2 1 1 0 1 1		34555.180	34555.18626	-0.00626	a		
1 0 1 1 2 1 1 0	.	35166.810	35166.95424	-0.14424	a		
2 1 1 0 1 1 0 0		35663.880	35663.88504	-0.00504	a		
2 1 1 1 1 1 0 1	.	35694.540	35694.55771	-0.01771	a		
7 1 6 1 7 2 6 0		36566.190	36566.27293	-0.08293	a		
3 1 3 0 2 1 2 0	.	50209.140	50209.17018	-0.03018	a		
3 1 3 1 2 1 2 1	.	50244.590	50244.45189	0.13811	a		
4 2 3 0 3 1 3 1	.	51362.918	51363.06201	-0.14401	a		
3 0 3 0 2 0 2 0		51724.330	51724.34450	-0.01450	a		
3 0 3 1 2 0 2 1		51742.140	51742.17291	-0.03291	a		
3 2 2 0 2 2 1 0		51847.750	51847.11071	0.03929	a		
3 2 2 1 2 2 1 1		51854.640	51854.61102	0.02898	a		
3 1 2 0 2 1 1 0	.	53472.603	53472.53243	0.07057	a		
3 1 2 1 2 1 1 1	.	53517.641	53517.66186	-0.02086			
0 0 0 1 1 1 0 0	.	53534.900	53535.03647	-0.13647			
4 1 4 0 3 1 3 0		66905.166	66905.22082	-0.05482			

TABLE I - *Continued*

J'Ka'Kc'TS'	J"Ka"Kc"TS"	Obs.	Freq.	Calc.	Freq.	Obs	-Calc	Ref.
			(MHz)		(MHz)		(MHz)	
4	1 4	1 3	1 3	66961.750	66961.75615	-0.00615		
4	0 4	0 3	0 3	68802.968	68802.99727	-0.02927		
4	0 4	1 3	0 3	6882.2.861	68822.89709	-0.03609		
4	2 3	0 3	2 2	69098.317	69098.31871	-0.00171		
14	1 13	1 14	2 13	69108.218	69108.39499	-0.17699		
4	2 3	1 3	2 2	69111.335	69111.33439	0.00061		
4	3 2	1 3	3 1	69219.273	69219.23805	0.03495		
4	3 1	1 3	3 0	69223.400	69223.38410	0.01590		
4	3 2	0 3	3 1	69262.000	69261.98662	0.01338		
4	3 1	0 3	3 0	69266.931	69266.97403	-0.04303		
4	2 2	0 3	2 1	69455.198	69455.21394	-0.01594		
4	2 2	1 3	2 1	69456.604	69456.58298	0.02102		
5	2 4	0 4	1 4	70712.540	70712.62944	-0.08944		
4	1 3	0 3	1 .	71252.139	71252.14679	-0.00779		
4	1 3	1 3	1 .	71311.479	71311.49306	-0.01406		
1	0 1	1 1	1 1	71918.992	71919.08924	-0.09724	b	
2	0 2	1 2	1 2	72986.578	72986.72920	-0.15120	b	
15	1 14	1 15	214 0	74188.188	74188.42030	-0.23230		
3	0 3	1 3	1 3	74519.642	74519.73192	-0.08992	b	
11	4 8	0 11	3 8	76049.810	76049.84003	-0.03003		
4	0 4	1 4	1 4	76437.327	76437.40819	-0.08119	b	
6	2 4	0 5	1 4	76728.037	76728.04862	-0.01162		
10	4 7	0 10	3 7	76855.345	76855.35540	-0.01040		
13	4 9	0 13	3 11	78633.773	78633.68973	0.08327		
5	0 5	1 5	1 5	"18637.457	78637.51020	-0.05320	b	
6	0 6	1 6	1 6	81003.969	81003.99087	-0.02187	b	
7	0 7	1 7	1 7	83417.055	83417.04178	0.01322	b	
17	4 13	0 17	3 1 5	83441.443	83441.44639	-0.00339		
5	1 5	0 4	1 4	83568.768	83568.81038	-0.04238		
5	1 5	1 4	1 4	83661.961	83661.97647	-0.01547		
5	0 5	0 4	0 4	85747.177	85747.22139	-0.04439	b	
8	0 8	1 8	1 8	85765.145	85765.08274	0.06226	b	
5	0 5	1 4	0 4	85768.904	85768.91239	-0.00839	b	
5	2 4	0 4	2 3	86311.299	86311.32359	-0.02459		
5	2 4	1 4	2 3	86344.210	86344.24223	-0.03223		
5	4 2	1 4	4 1	86516.535	86516.51636	0.01864		
5	4 1	1 4	4 0	86516.535	86516.60732	-0.07232		
5	3 3	1 4	3 2	86550.416	8655"0.41372	0.00228		
5	4 2	0 4	4 1	86555.958	86555.94374	0.01426		
5	4 1	0 4	4 0	86555.958	86556.04281	-0.08481		
5	3 2	1 4	3 1	86564.842	86564.89959	-0.05759		
5	3 3	0 4	3 2	86604.336	86604.32550	0.01050		
5	3 2	0 4	3 1	86621.712	86621.76545	-0.05345		
5	2 3	1 4	2 2	87027.131	87027.16603	-0.03503		
5	2 3	0 4	2 2	87030.007	87030.03439	-0.02739		
13	5 9	1 14	4 11	87899.495	87899.76641	-0.27141		
9	0 9	1 9	1 9	87959.044	87958.88706	0.15694	b	
5	1 4	0 4	1 3	88991.173	88991.19996	-0.02696	b	

TABLE I - *Continued*

J'	K_a'	K_c'	T_S'	J''	K_a''	K_c''	T_S''	Obs . Freq. (MHz)	Calc. Freq. (MHz)	Obs-Calc (MHz)	Ref.
5	1	4	1	4	1	3	1	89065.329	89065.35978	-0.03078	
1	0	0	1	0	1	1	0	89946.985	89946.88662	0.09838	b
2	2	3	2	0	0	2	1	91648.772	91648.60104	0.17096	
1	1	0	1	1	1	1	1	91737.258	91736.98779	0.27021	b
1	5	1	1	4	0	1	4	91939.228	91938.83076	0.39724	
2	2	1	2	1	1	2	2	92156.535	92156.74773	-0.21273	
2	3	4	1	9	0	2	2	92426.377	92427.71647	-1.33947	
1	3	1	1	2	0	1	3	93279.005	93278.91430	0.09070	
1	2	0	1	2	1	1	2	93477.574	93477.51025	0.06375	
1	4	0	1	4	1	1	4	93497.421	93497.30160	0.11940	
2	3	1	2	2	1	2	3	93568.872	93568.98502	-0.11302	
1	5	0	1	5	1	1	5	94696.400	94696.24269	0.15731	
2	5	5	2	1	0	2	5	95001.306	95000.28468	1.02132	
7	2	5	1	6	3	3	0	95111.248	95111.34054	-0.09254	
1	0	3	8	1	9	4	6	95365.486	95365.52958	-0.04358	
1	6	0	1	6	1	1	6	95416.499	95416.44246	0.05654	
4	1	3	1	3	2	1	0	95422.207	95422.27604	-0.06904	
2	5	1	2	4	1	2	5	95546.737	95546.13092	0.60608	
1	3	0	1	3	1	1	3	95607.001	95607.07319	-0.07219	*
1	7	0	1	7	1	1	7	95924.429	95924.40747	0.02153	
4	2	3	1	5	1	5	0	96189.497	96188.87780	0.61920	
1	8	0	1	8	1	1	8	96301.745	96301.81790	-0.07290	
1	0	3	7	1	9	4	5	96501.216	96501.25761	-0.04161	
1	9	0	1	9	1	1	9	96589.675	96589.82816	-0.15316	
2	7	1	2	6	1	2	7	96770.947	96769.07224	1.87476	
2	0	0	2	0	1	2	0	96814.1.72	96814.37685	-0.20485	
1	6	1	1	5	1	1	5	96899.450	96899.66862	-0.21862	
2	1	0	2	1	1	2	1	96993.077	96993.38199	-0.30499	
2	2	0	2	2	1	2	2	97138.965	97139.67540	-0.71040	
2	3	0	2	3	1	2	3	97263.540	97262.56848	0.97152	
24	0	24	1	2	4	1	2	97369.103	97368.84234	0.26066	
2	5	0	2	5	1	2	5	97463.678	97463.43279	0.24521	
2	2	1	2	2	1	2	2	97525 .?"98	9"1526.06762	-0.26962	
2	1	1	2	1	1	2	1	97535.908	9"7536.10688	-0.19888	
2	3	1	2	3	1	2	3	97536.849	97536.81410	0.03490	
2	6	0	2	6	1	2	6	97549.692	97549.92425	-0.23225	
24	1	24	1	2	4	0	2	97562.811	97562.94438	-0.13338	
2	0	1	2	0	1	2	0	97574.005	97574.12954	-0.12454	
2	5	1	2	5	1	2	5	97600.390	97600.46013	-0.07013	
2	7	0	2	7	1	2	7	97631.329	97630.91.173	0.41727	
2	6	1	2	6	1	2	6	97645.192	97646.43353	-1.24153	
1	9	1	1	9	1	1	9	97649.502	97649.54467	-0.04267	
27	1	2	7	1	2	7	0	97698.530	97698.73902	-0.20902	
2	8	0	2	8	1	2	8	97708.888	97708.26737	0.62063	
2	8	1	2	8	1	2	8	97755.610	97755.84400	-0.23400	
1	8	1	1	8	1	1	8	97-/74.307	97774.29937	0.00763	
2	9	0	2	9	1	2	9	97784.113	97783.33655	0.77645	
2	9	1	2	9	1	2	9	97815.987	97816.64920	-0.66220	

TABLE I - Continued

J'Ka'Kc'TS'	J"Ka"Kc"TS"	Obs.	Freq. (MHz)	Calc. Freq. (MHz)	Obs-Calc (MHz)	Ref.
3 0 0	3 0 1 3 0 1 3 0 0	97857.444	97857.08167	0.36233		
1 7 1	1 7 1 1 7 0 1 7 0	97962.834	97962.18448	0.04952		
4 3 1	0 3 2 1 1	98005 .465	98005.51240	-0.04740		
4 3 2	0 3 2 2 1	98173.366	98173.42561	-0.05961		
1 6 1	1 6 1 1 6 0 1 6 0	98230.313	98230.23064	0.08236		
1 . 5 1	1 5 1 1 5 0 1 5 0	98585.095	98584.96954	0.12546		
2 9 2	2 8 1 2 9 1 2 8 0	988?3.691	98824.80609	-1.11509		
1 3 4	1 0 1 1 2 5 8 0	98844.461	98844.58351	-0.12251		
1 3 0	1 3 1 1 3 0 1 3 0	98878.281	98878.35420	-0.07320 *		
1 7 2	1 5 0 1 6 3 1 3 1	98881.085	98881.39084	-0.30584		
2 8 2	2 7 1 2 8 1 . 2 7 0	98946.244	98946.30355	-0.05955		
1 4 1	1 4 1 1 4 0 1 4 0	98983.548	98983.47624	0.07176		
1 3 1	1 3 1 1 3 1 1 3 0	99109.251	99108.57923	0.67177 *blend		
13 4	9 112 5 7 0	99109.251	99109.80634	-0.55534 blend		
2 7 2	2 6 1 2 7 1 2 6 0	99143.725	99143.53955	0.18545		
5 1	5 1 4 2 3 0	99260.691	99260.67062	0.02038		
2 6 2	2 5 1 2 6 1 2 5 0	99440.000	99439.91674	0.08326		
2 5 2	2 4 1 2 5 1 2 4 0	99864.418	99864.47967	-0.06167		
3 2 1	1 4 1 3 0	99945.278	99945.20924	0.06876		
6 1 6	0 5 1 5 0	100194.326	100194.36719	-0.04119		
6 1	6 1 5 1 5 1	1.00365.052	100365.06777	-0.01577		
2 3 2	2 2 0 2 2 3 2 0 1	100372.258	100371.44477	0.81323		
2 1 4	1 7 0 2 1 3 1 9 1	100438.643	100439.22030	-0.57730		
2 4 2	2 3 1 2 4 1 2 3 0	100452.072	100452.29809	-0.22609		
2 3 2	2 2 1 2 3 1 2 2 0	101243.633	101243.99499	-0.36199		
11 1	1 1 1 1 1 0 1 1 0	102489.386	102489.05581	0.33019		
6 3 3	1 7 2 5 0	102498.891	102498.74685	0.14415		
6 0 6	0 5 0 5 0	102534.06"/	102534.10165	-0.03465		
6 0	6 1 5 0 5 1	102560.844.	102560.84787	-0.00387		
6 2 5	0 5 2 4 0	103452.165	103452.18385	-0.01885		
1 6 1	1 5 0 1 5 2 1 3 1	103525.945	103525.58459	0.36041		
6 2 5	1 5 2 4 1	103547.735	103547.76967	-0.03467		
2 1 2	2 0 1 2 1 1 2 0 0	103608.598	103608.80237	-0.20437		
1 0 1	1 0 1 1 0 0 1 0 0	103796.950	103796.68093	0.26907		
6 5 2	1 5 5 1 1	103810.487	103810.50261	-0.01561		
6 5 1	1 5 5 1 1	103810.48'/	103810.50446	-0.01746		
6 4 3	1 5 4 2 1	103843.384	103842.85457	0.52943 blend		
6 4 2	1 5 4 1 1	103843.384	103843.26345	0.12055 blend		
6 5 2	0 5 5 1 0	103863.384	103863.43882	-0.05482		
6 5 1	0 5 5 0 0	103863.384	103863.44065	-0.05665		
6 4 3	0 5 4 2 0	103890.904	103890.71576	0.18824		
6 4 2	0 5 4 1 0	103890.904	103891.16108	-0.25708		
6 3 4	1 5 3 3 1	103895.533	103895.54219	-0.00919		
6 3 3	1 5 3 2 1	103934.013	103934.05716	-0.04416		
6 3 4	0 5 3 3 0	103960.442	103960.45157	-0.00957		
6 3 3	0 5 3 2 0	104006.866	104006.89627	-0.03027		
7 2 6	0 7 0 7 0	104718.654	104718.64296	0.01104		
6 2 4	1 5 2 3 1	104720.8-/3	104720.91183	-0.03883		

TABLE I - *Continued*

J'Ka'Kc' TS	J"Ka"Kc"TS"	Obs. Freq. (MHz)	Calc. Freq. (MHz)	Ohs-Calc (MHz)	Ref.
6 2 4 0 5 2 3 0		104730.411	104730.43611	-0.02511	
2 0 2 1 9 1 2 0 1 1 9 0		105225.485	105225.77583	-0.29083	
2 0 2 1 1 1 0 0		105385.871	105386.02555	-0.15455	
8 2 7 0 8 0 8 0		105731..717	105731.55104	0.16596	
12 5 8 113 4 10 0		105741..027	105741.23407	-0.20707	
6 1 5 0 5 1 4 0		106676.542	106676.46544	0.07656	
6 1 5 1 5 1 4 1		106767.234	106767.26363	-0.02963	
14 1 13 1 14 1 14 1		108753.950	108754.06180	-0.11180	
8 1 8 1 8 0 8 0		110368.495	110368.59430	-0.09930	
7 1 7 1 7 0 7 0		111344.327	111344.32763	-0.00063	
22 5 18 022 4 18 1		111412.990	111412.40284	0.58716	
9 1 8 0 8 0 8 1		112269.238	112269.19572	0.04228	
21 5 17 021 4 17 1		115124.208	115123.82680	0.38120	
5 3 2 0 4 2 2 1		1.15170 653	115170.69487	-0.04187	
21 2 19 1 20 4 1.6 1		115320.567	115320.58600	-0.01900	
5 1 5 1 5 0 5 0		11.5494.515	115494.54428	-0.02928	
5 3 3 0 4 2 3 1		1.15666.317	115666.41672	-0.09972	
7 1 7 0 6) 6 0		1.16777.812	116777.84451	-0.03251	
7 1 7 1 6 1 . 6 1		117171.535	117171.58610	-0.05110	
4 1 4 1 4 0,4 0		117579.752	117579.78920	-0.03720	
16 2 15 1 16 1. 15 0		117710.218	117710.60718	-0.38918	
7 0 7 0 6 0 6 0		119152.733	119152.76888	-0.03588	
7 0 7 1 6 0 6 1		119190.891	119190.89542	-0.00442	
19 5 15 019 4 15 1		120417.465	120417.25265	0.21235	
7 2 6 1 6 2 5 1		120716.545	120716.59695	-0.05195	
2 1 2 1 2 0 2 0		120900.880	120900.92293	-0.04293	c
7 6 2 1 6 6 1 1		121103.099	121103.13274	-0.03374	
7 6 1 1 6 6 0 1		121103.099	121103.13276	-0.03376	
7 5 3 1 6 5 2 1		121131.030	121131.05393	-0.02393	
7 5 2 1 6 5 1 1		121131.030	121131.06322	-0.03322	
7 6 2 0 6 6 1 0		121176.485	121176.57283	-0.08783	
7 6 1 0 6 6 0 0		121176.485	121176.57286	-0.08786	
7 4 4 1 6 4 3 1		121181.554	121181.54124	0.01276	
7 4 3 1 6 4 2 1		121182.812	121182.90194	-0.08994	
7 5 3 0 6 5 2 0		121193.089	121193.15358	-0.06458	
7 5 2 0 6 5 1 0		121193.089	121193.16363	-0.07463	
7 4 4 0 64 3 0		121238.1.58	121238.12237	0.03563	
7 4 3 0 6 4 2 0		121239.525	121239.60430	-0.07930	
7 3 5 1 6 3 4 1		121253.961	121.253.98639	-0.02539	
7 3 5 0 6 3 4 0		121329.276	121329.30611	-0.03011	
7 3 4 1 6 3 3 1		121340.1.85	121.340.24031	-0.05531	
7 3 4 0 6 3 3 0		121433.611	121433.61948	-0.00848	
3 0 3 1 2 1 1 0		121464.1.41	121464.31341	-0.17241	
15 2 14 1 15 1 14 0		121496.294	121496.65793	-0.36393	
1 1 1 1 1 0 1 0		121933.986	121.934.02849	-0.04249	b
7 2 5 1 6 2 4 1		122540.812	122540.85382	-0.04182	
7 1 6 0 6 1 5 0		124292.388	124292.41772	-0.02972	
7 1 6 1 6 1 5 1		124403.460	124403.46735	-0.00735	

TABLE 1- *Continued*

J'Ka'Kc'TS'	J"Ka"Kc"TS"	Obs .	Freq.	Cal.c.	Freq.	Obs-Calc	Ref.
		(MHz)		(MHz)		(MHz)	
8 1 8 0 7 1 7 0		133316.792		133316.83797		-0.04597	
8 0 8 0 7 0 7 0		135608.030		135608.06041		-0.03041	
8 0 8 1 7 0 7 1		135664.865		135664.87894		-0.01394	
1 3 2 1 2 1 1 3	1 1 2 0	135668.020		135668.06525		-0.04525	
8 2 7 0 7 2 6 0		136621.050		136620.96849		0.08151	
8 2 7 1 7 2 6 1		137845.614		137845.67048		-0.05648	
8 7 1 1 7 7 0 1		1.38394.881		138394.91664		-0.03564	
8 7 2 1 7 7 1 1		138394.881		138394.91664		-0.03564	
8 6 3 1 7 6 2 1		138419.248		138419.28589		-0.03789	
8 6 2 1 7 6 1 1		1.38419.248		138419.28607		-0.03807	
8 5 4 1 7 5 3 1		138460.257		138460.27452		-0.01752	
8 5 3 1 7 5 2 1		138460.257		138460.31160		-0.05460	
8 7 1 0 7 7 0 0		138493.534		138493.65852		-0.12452	
8 7 2 0 7 7 1 0		138493.534		138493.65852		-0.12452	
8 6 3 0 7 6 2 0		138503.327		138503.43447		-0.10747	
8 6 2 0 7 6 1 0		138503.327		138503.43467		-0.10767	
8 5 4 0 7 5 3 0		138531.634		138531.69068		-0.05668	
8 5 3 0 7 5 2 0		138531.634		138531.73085		-0.09685	
8 4 5 1 7 4 4 1		138534.327		138534.33340		-0.00640	
8 4 4 1 7 4 3 1		138538.010		138538.06645		-0.05645	
8 4 5 0 7 4 4 0		138599.921		138599.94748		-0.02648	
8 4 4 0 7 4 3 0		138603.960		138604.01307		-0.05307	
8 3 6 1 7 3 5 1		138623.475		138623.51965		-0.04465	
8 3 6 0 7 3 5 0		138708.129		138708.16599		-0.03699	
8 3 5 1 7 3 4 1		138794.762		138794.81599		-0.05399	
8 3 5 0 7 3 4 0		138916.337		138916.33397		0.00303	
1 1 0 1 0 0 0 0		140316.505		140316.51164		-0.00664	b
8 2 6 1 7 2 5 1		140473.158		140473.17676		-0.01876	
8 2 6 0 7 2 5 0		140506.812		140506.83677		-0.02477	
8 1 7 0 7 1 6 0		141820.317		141820.37149		-0.05449	
8 1 7 1 7 1 6 1		141958.185		141958.26854		-0.08354	
9 1 9 0 8 1 8 0		149810.554		149810.59410		-0.04010	
7 3 5 0 6 2 5 1		151064.099		151064.16250		-0.06350	
9 0 9 0 8 0 8 0		151920.752		151920.78737		-0.03537	
9 0 9 1 8 0 8 1		152004.406		152004.39841		0.00759	
9 2 8 1 8 2 7 1		154930.188		154930.21598		-0.02798	
9 8 1 1 8 8 0 1		155686.475		155686.58801		-0.11301	
9 8 2 1 8 8 1 1		155686.475		155686.58801		-0.11301	
9 7 2 1 8 7 1 1		155707.396		155707.45289		-0.05689	
9 7 3 1 8 7 2 1		155"107.396		15570"1.45289		-0.05689	
9 6 4 1 8 6 3 1		155741.683		155741 ."11.518		-0.03218	
9 6 3 1 8 6 2 1		155741.683		155741.71604		-0.03304	
9 5 5 1 8 5 4 1		155799.415		155799.39511		0.01989	
9 5 4 1 8 5 3 1		155799.415		155799.51542		-0.10042	
9 8 1 0 8 8 0 0		155813.723		155813.85956		-0.13656	
9 8 2 0 8 8 1 0		155813.723		155813.85956		-0.13656	
9 7 2 0 8 7 1 0		155818.633		155818.67390		-0.04090	
9 7 3 0 8 7 2 0		155818.633		155818.67390		-0.04090	

TABLE I - *Continued*

J'Ka'Kc'TS'	J"Ka"Kc"TS"	Obs .	Freq.	Cal c.	Ii'req.	Obs-Calc	Ref.
(MHz)	(MHz)	(MHz)		(MHz)	(MHz)	(MHz)	
9 6 4 0 8	6 3 0	155836.545	155836.65408	-0.10908			
9 6 3 0 8	6 2 0	155836.545	155836.65501	-0.11001			
9 5 5 0 8	5 4 0	155880.376	155880.29957	0.07643			
9 5 4 0 8	5 3 0	155880.376	155880.42985	-0.05385			
9 4 6 1 8	4 5 1	155902.683	155902.72379	-0.04079			
9 4 5 1 8	4 4 1	155911.554	155911.65348	-0.09948			
9 4 6 0 8	4 5 0	155977.653	155977.69111	-0.03811			
9 4 5 0 8	4 4 0	155987.365	155987.41623	-0.05123			
9 3 7 1 8	3 6 1	156000.277	156000.31815	-0.04115			
9 3 7 0 8	3 6 0	156092.693	156092.731.50	-0.03850			
9 3 6 1 8	3 5 1	156311.1.39	156311.17340	-0.03440			
9 3 6 0 8	3 5 0	156473.455	156473.47059	-0.01559			
9 2 7 1 8	2 6 1	158485.752	158485.80449	-0.05249			
9 2 7 0 8	2 6 0	158541.644	158541.66909	-0.02509			
2 1 1 1 1	0 1 0	158722.426	158722.65066	-0.22466	b		
'9 1 8 0 8	1 7 0	159236.782	159236.80702	-0.02502			
9 1 8 1 8	1 7 1	159414.050	159414.07967	-0.02967			
11 1 10 0 10	0 10 1	1.62097.990	162097.95954	0.03046			
8 3 5 0 7	2 5 1	165238.604	165238.61291	-0.00891			
5 2 4 1 5	1 4 0	1.66235.871	166235.85356	0.01744			
10 110 0 9	1 9 0	166259.891	166259.90359	-0.01259			
10 01.0 0 9	0 9 0	1.68123.386	168123.41844	-0.03244			
10 010 1 90	9 1	168247.911	168247.90315	0.00785			
8 3 6 0 7	2 6 1	169055.693	169055.73154	-0.03854			
3 2 2 1 3	1 2 0	171023.183	171023.62368	-0.44068	c		
1 0 2 9 0	9 2 8	1715'70.168	171570.17398	-0.00598			
10 2 9 1 9	2 8 1	171965.743	171965.77471	-0.03171			
2 2 1 1 2	1 1 0	172641.532	172641.54509	-0.01309	c		
10 9 1 1 9	9 0 1	172979.109	172978.99840	0.11060			
10 9 2 1 9	9 1 1	172979.109	172978.99840	0.11060			
1 0 8 2 1 9	8 1 1	172995.960	172995.99643	-0.03643			
10 8 3 1 9	8 2 1	172995.960	172995.99643	-0.03643			
10 7 4 1 97	3 1	173024.634	173024.62902	0.00498			
1 0 7 3 1 9	7 2 1	173024.634	173024.62904	0.00496			
10 6 5 1 96	4 1	173071.168	173071.20478	-0.03678			
10 6 4 1 9	6 3 1	173071.168	173071.20798	-0.03998			
10 9 1 0 9	9 0 0	173136.465	173136..54601	-0.08101			
1 0 9 2 0 9	9 1 0	173136.465	173136.54601	-0.08101			
10 8 2 0 9	8 1 0	173137.396	173137.49276	-0.09676			
1 0 8 3 0 9	8 2 0	173137.396	173137.49276	-0.09676			
10 7 4 0 97	3 0	173148.257	173148.37271	-0.11571			
1 0 7 3 0 9	7 2 0	173148.257	173148.37273	-0.11573			
10 5 6 1 95	5 1	173149.762	173149.63661	0.12539			
1 0 5 5 1 9	5 4 1	173149.762	173149.97274	-0.21074			
10 6 5 0 9	6 4 0	173176.970	1.73177.02312	-0.05312			
1 0 6 4 0 9	6 3 0	173176.970	173177.02661	-0.05661			
1 0 5 6 0 9	5 5 0	173240.099	173240.21801	-0.11901			
1 0 5 5 0 9	5 4 0	173240.099	173240.58187	-0.48287			

TABLE I - *Continued*

J'Ka'Kc'TS'	J"Ka"Kc"TS"	Obs .	Freq.	Calc. Freq.	Obs-Calc	Ref.
			(MHz)	(MHz)	(MHz)	
1 0 4 7 1 9 4 6 1		173287.772	173287.82229	-0.05029		
1 0 4 6 1 9 4 5 1		173307.040	173307.08314	-0.04314		
1 0 4 7 0 9 4 6 0		173372.426	173372.44244	-0.01644		
10 38 1 9 3 7 1		173379.040	173379.07132	-0.03132		
21 2 1 9 0 2 0 3 1 7 1		173391.356	173390.29120	1.06480		
1 0 4 6 0 9 4 5 0		173393.388	173393.41937	-0.03137		
1 0 3 8 0 9 3 7 0		173477.348	173477.33740	0.01060		
1 0 3 7 1 9 3 6 1		173904.356	173904.38473	-0.02873		
1 0 3 7 0 9 3 6 0		174128.703	174128.72173	-0.01873		
14 6 8 0 14 5 10 1		175615.535	175615.99177	-0.45677		
2 2 0 1 2 1 . 2 0		175941.350	175940.95519	0.39481	C	
10 1 9 09 1. 8 0		176508.525	176508.53880	-0.01380		
1 0 2 8 1 9 2 7 1		176530.663	176530.72782	-0.06482		
10 2 8 09 2 7 0		176623.000	176623.04980	-0.04980		
1 0 1 9 1 9 1 8 1		176752.000	176752.01422	-0.01422		
3 1 2 1 2 0 2 0		177698.327	177698.76577	-0.43877	C	
3 2 1 1 3 1 3 0		177725.590	177725.30696	0.28304	C	
6 4 2 0 5 3 2 1		181952.495	181952.38037	0.11463		
6 4 3 0 5 3 3 1		181971.107	181971.14717	-0.04017		
11 2 10 010 2 9 0		188801.871	188801.84112	0.02988		
11 2 10 1 10 2 9 1		188948.317	188948.31444	0.00256		
11 92 110 9 1 1		190285.693	190285.63891	0.05409		
11 9 3 110 9 2 1		190285.693	190285.63891	0.05409		
11 8 3 110 8 2 1		190308.822	190308.83538	-0.01338		
11 8 4 110 8 3 1		190308.822	190308.83538	-0.01338		
11 7 5 110 7 4 1		190346.901	190346.95781	-0.05681		
11 74 110 7 3 1		190346.901	190346.95789	-0.05689		
11 6 6 110 6 5 1		190408.564	190408.54122	0.02278		
11 6 5 110 6 4 1		190408.564	190408.55146	0.01254		
11 9 2 010 9 1 0		190459.059	190458.98428	0.07472		
11 9 3 010 9 2 0		190459.059	190458.98428	0.07472		
11 10 1 010 10 0 0		1.90461.292	190461.21015	0.08685		
11 10 2 010 10 1 0		190461.29-/	190461.21015	0.08685		
11 8 3 010 8 2 0		190464.564	190464.57989	-0.01589		
11 84 010 8 3 0		190464.564	190464.57989	-0.01589		
11 7 5 010 7 4 0		190483.188	190483.27009	-0.08209		
11 7 4 0107 3 0		190483.188	190483.27017	-0.08217		
11 5 7 110 5 6 1		190512.139	190512.19937	-0.06037		
11 5 6 110 5 5 1		190512.950	190513.03727	-0.08727		
11 6 6 010 6 5 0		190525.219	190525.33453	-0.11553		
11 6 5 0106 4 0		190525.219	190525.34567	-0.12667		
15 3 13 1 15 2 13 0		190569.355	190569.52300	-0.16800		
11 57 010 5 6 0		190612.624	190612.66036	-0.03636		
11 5 6 010 5 5 0		190613.515	190613.56709	-0.05209		
11 4 8 1104 7 1		190690.218	190690.21625	0.00175		
11 4 7 110 4 6 1		190728.485	190728.50903	-0.02403		
11 3 9 110 3 8 1		190753.139	190753.20436	-0.06536		
11 4 8 010 4 7 0		190784.743	190784.73110	0.01190		

TABLE 1- *Continued*

J'Ka'	Kc'	Ts'	J"Ka"	Kc"	Ts"	Obs .	Freq.	Calc.	Freq.	Obs-Calc	Ref.			
						(MHz)		(MHz)		(MHz)				
11	4	7	010	4	6	0	190826.426	190826.43751	-0.01151					
11	3	9	010	3	8	0	1.90855.307	190855.23309	0.07391					
11	3	8	110	3	7	1	191590.287	191590.24647	0.04053					
11	3	8	010	3	7	0	191912.871	191912.81096	0.06004					
11	1	1	0	0	1	0	193572.516	193572.52658	-0.01058					
1	1	1	1	0	1	1	0	193953.317	193953.33703	-0.02003				
11	2	9	110	2	8	1	194548.366	194548.38908	-0.02308					
11	2	9	010	2	8	0	194703.406	194703.41911	-0.01311					
12	1	12	0	11	1	1	1	199034.723	199034.71058	0.01242				
7	4	3	0	6	3	3	1	199257.932	199257.92752	0.00448				
7	4	4	0	6	3	4	1	199313.656	199313.72735	-0.07135				
12	1	12	1	11	1	11	1	199386.044	199385.92201	0.12199				
12	012	0	11	0	11	0	0	200341.535	200341.51361	0.02139				
12	012	1	11	0	11	1	0	200775.228	200775.23304	-0.00504				
12	2	11	011	2	10	0	0	205794.545	205794.46452	0.08048				
1	0	3	8	0	9	2	8	1	205849.985	205849.91398	0.07102			
12	2	11	1	11	2	10	1	205874.515	205874.48516	0.02984				
12	9	3	111	9	2	1	0	20"1594.782	207594.76306	0.01894				
12	9	4	111	9	3	1	0	20'7594.782	207594.76306	0.01894				
12	84		111	8	3	1	0	207625.337	207625.44373	-0.10673				
12	8	5	111	8	4	1	0	207625.337	207625.44373	-0.10673				
12	7	6	1	11	7	5	1	207674.851	207674.95272	-0.10172				
12	7	5	111	7	4	1	0	207674.851	207674.95299	-0.10199				
12	67		111	6	6	1	0	207754.465	20"1754.51452	-0.04952				
12	6	7	111	6	6	1	0	207754.465	207754.51452	-0.04952				
12	6	6	111	6	5	1	0	207754.465	207754.54344	-0.07844				
12	6	6	111	6	5	1	0	207754.465	207754.54344	-0.07844				
12	10	2	011	10	1	0	0	207782.376	207782.47916.	-0.10316				
12	10	3	011	10	2	0	0	207782.376	207782.47916	-0.10316				
12	9	3	011	9	2	0	0	207784.188	207783.91905	0.26895				
1.2	9	4	011	9	3	0	0	207784.188	207783.91905	0.26895				
12	11	1	0	11	11	0	0	207787.693	207787.53401	0.15899				
1	2	1	1	2	0	1	1	1	207787.693	207787.53401	0.15899			
12	84		011	8	3	0	0	207795.436	207795.46064	-0.02464				
)	2	8	5	011	8	4	0	207795.436	207795.46064	-0.02464				
12	7	6	011	7	5	0	0	207823.792	207823.88112	-0.08912				
1	2	7	5	0	1	1	7	4	0	207823.792	207823.88142	-0.08942		
1	2	6	7	0	1	1	6	6	0	207882.188	207882.38371	-0.19571		
1.2	6	6	011	6	5	0	0	20"1882.188	207882.41519	-0.22719				
12	5	8	111	5	7	1	0	207888.188	207888.24507	-0.05707				
12	5	7	111	5	6	1	0	207890.089	207890.15331	-0.06431				
6	5	2	1	5	5	0	0	207906.415	207905.68344	0.73156				
6	5	1	1	5	5	1	0	207906.416	207905.68548	0.73052				
12	5	8	011	5	7	0	0	207998.792	207998.79801	-0.00601				
12	5	7	011	5	6	0	0	208000.782	208000.86224	-0.08024				
12	4	9	111	4	8	1	0	208109.792	208109.81679	-0.02479				
1	2	3	1	0	1	1	1	3	9	1	208115.139	208115.19106	-0.05206	
12	4	8	111	4	7	1	0	208181.020	208181.06149	-0.04149				

TABLE I - *Continued*

J'K _a 'K _c 'TS'	J"K _a "K _c "7'S"	Obs.	Freq. (MHz)	Cal c. (MHz)	Freq. (MHz)	Obs-Calc (MHz)	Ref.
12 4 9 011 4 8 0		208214.356	208214.36510	-0.00910			
1 2 3 1 0 0 1 1 3 9 0		208218.842	208218.86670	-0.02470			
12 4 8 011 4 7 0		208291.941	208291.96737	-0.02637			
12 3 9 111 3 8 1		209383.475	209383.44253	0.03247			
2 2 1 1 1 1 0		209393.693	209393.68009	0.01291			
1 9 4 1 5 1 1 8 5 1 3 0		209537.832	209537.74686	0.08514			
12 3 9 011 3 8 0		209865.168	209865.17109	-0.00309			
1 2 1 1 1 0 1 1 1 0 0		210208.440	210208.46487	-0.02487			
12 1 11 1 1 1 1 1 0 1		211002.366	211002.36507	0.00093			
1 2 2 1 0 1 1 1 2 9 1		212471.337	212471.33828	-0.00128			
1 2 2 1 0 0 1 1 2 9 0		212735.287	212735.25031	0.03669			
1 3 1 1 3 0 1 2 1 1 2 0		215367.267	215367.23194	0.03506			
1 3 0 1 3 0 1 2 0 1 2 0		216415.624	216415.63476	-0.01076			
1 3 2 1 2 0 1 2 2 1 1 0		222677.109	222676.98504	0.12396			
1 3 2 1 2 1 1 2 2 1 1 1		222742.139	222742.12977	0.00923			
1 8 7 1 2 0 1 8 6 1 2 1		224540.911	224541.32603	-0.41503			
1 8 7 1 1 0 1 8 6 1 3 1		224547.238	224547.65960	-0.42160			
14 7 8 014 6 8 1		224552.436	224551.99889	0.43711			
14 7 7 014 6 9 1		224552.436	224552.99598	0.14002			
11 3 9 0102 9 1		224739.287	224739.37236	-0.08536			
1 3 1 1 2 0 1 2 1 1 1 0		224823.129	224823.15356	-0.02456			
1 3 1 1 2 1 1 2 1 1 1 1		224872.644	224871.08527	1.55873			
1 3 1 1 3 1 1 2 1 1 2 1		224872.644	224871.08527	1.55873			
1 3 1 0 3 1 1 2 1 0 2 1		224883.574	224883.02513	0.54887			
1 3 1 0 4 1 1 2 1 0 3 1		224883.574	224883.02513	0.54887			
13 9 4 112 9 3 1		224906.584	224906.59144	-0.00744			
13 9 5 112 9 4 1		224906.584	224906.59144	-0.00744			
1 6 2 1 5 1 1 5 3 1 3 0		224923.832	224923.71157	0.12043			
13 8 6 112 8 5 1		224946.040	224946.16011	-0.12011			
13 8 5 112 8 4 1		224946.040	224946.16012	-0.12012			
6 3 4 1 6 2 4 0		225001.204	225001.04505	0.15895			
13 7 7 112 7 6 1		225008.990	225009.12878	-0.13878			
13 7 6 112 7 5 1		225008.990	225009.12963	-0.13963			
1 3 1 0 3 0 1 2 1 0 2 0		225105.188	225105.46335	-0.27535			
1 3 1 0 4 0 1 2 1 0 3 0		225105.188	225105.46335	-0.27535			
1 3 1 1 2 0 1 2 1 1 1 0		225107.881	225107.55505	0.32595			
1 3 1 . 1 3 0 1 2 1 1 2 0		225107.881	225107.55505	0.32595			
13 6 8 112 6 7 1		225109.881	225109.91898	-0.03798			
13 6 7 112 6 6 1		225109.88J	225109.99314	-0.11214			
13 9 4 012 9 3 0		225112.095	225111.57218	0.52282			
13 95 012 9 4 0		225112.095	225111.57218	0.52282			
13 12 1 0 1 2 1 2 0 0		225115.663	225115.55225	0.11075			
1 3 1 2 2 0 1 2 1 2 1 0		225115.663	225115.55225	0.11075			
13 8 6 012 8 5 0		225130.505	225130.47402	0.03098			
13 8 5 012 8 4 0		225130.505	225130.47403	0.03097			
13 7 7 012 7 6 0		225170.614	225170."10.72169	-0.10769			
13 7 6 012 7 5 0		225170.614	225170."?2262	-0.10862			
7 5 3 1 6 5 1 0		225172.772	225173.29672	-0.52472			

TABLE I - *Continued*

J'Ka'Kc'TS'	J"Ka"Kc"TS"	Obs.	Freq.	Calc.	Freq.	Obs-Calc	Ref.
			(MHz)		(MHz)	(MHz)	
7 5 2 1 6	5 2 0	225172.772	225173.30988	-0.53788			
13 6 8 012	6 7 0	225248.812	225248.96923	-0.15723			
13 6 7 012	6 6 0	225248.812	225249.04992	-0.23792			
13 5 9 112	5 8 1	225278.851	225278.86878	--0.01778			
13 5 8 112	5 7 1	225282.851	225282.90536	-0.05436			
13 5 9 012	5 8 0	225399.733	225399.72920	0.00380			
13 5 8 012	5 7 0	225404.089	225404.09402	-0.00502			
13 3 11 1 12	3 10 1	225456.911	225456.92393	-0.01293			
13 4 10 1 12	4 9 1	225545.693	225545.70240	-0.00940			
13 3 11 0 12	3 10 0	225560.109	225560.13014	-0.02114			
13 4 10 012	4 9 0	225660.277	225660.26858	0.00842			
13 4 9 112	4 8 1	225671.099	225671.10956	-0.01056			
13 4 9 012	4 8 0	225796.891	225796.88498	0.00602			
13 310 1 12	3 9 1	227294.752	227294.68876	0.06324			
13 1 12 1 12	1. 11 1	227891.911	227891.88922	0.02178			
13 3 10 0 12	3 9 0	228029.050	228029.05652	-0.00652			
13 2 11 1 12	2 10 1	230230.743	230230.70495	0.03805			
13 2 11 0 12	2 10 0	230672.554	230672..51236	0.04164			
10 3 7 110	2 9 0	231220.812	231220.62970	0.18230			
18 1 18 1 17	2 16 0	231568.693	231568.69032	0.00268			
14 1 14 013	1 13 0	231668.733	231668.67915	0.05385			
1 4 0 1 4 0 1 3	0 1 3 0	232491..366	232491 .26349	0.10251			
14 1 14 1 1 3 0 1	3 1 1 2 0	232596.554	232596.38553	0.16847 *			
1 4 0 1 4 1 1 3	1 1 2 0	235158.455	235158.34747	0.10753			
1 7 2 1 . 6 1 1 6	3 1 4 0	237379.376	237379.32721	0.04879			
1 4 2 1 3 0 1 3	2 1 2 0	239478.079	239477.99134	0.08766			
1 4 2 1 3 1 1 3	2 1 2 1	239551.366	239551.35016	0.01584			
2 1 4 1 . 8 1 2 0	5 1 6 0	239912.139	239912.93909	-.0.80009			
1 4 1 3 1 1 1 3	1 3 0 1	242166.644	242167.65430	--1.01030			
1 4 1 3 2 1 1 3	1 3 1 1	242166.644	242167.65430	-1.01030			
1 4 1 1 3 1 1 3	1 1 2 1	242175.455	242174.11567	1.33933			
1 4 1 1 4 1 1 3	1 1 3 1	242175.455	242174.11567	1.33933			
1 4 1 0 4 1 1 3	1 1 0 3 1	242191.297	242190.75518	0.54182			
1 4 1 0 5 1 1 3	1 0 4 1	242191.297	242190.75518	0.54182			
1 3 3 1 . 0 1 1 3	2 1 2 0	242215.792	242215.71679	0.07521			
1 4 9 5 1 1 3 9	4 1	242221.27"/	242221.34387	-0.06687			
14 9 6 113	9 5 1	242221.277	242221.34387	-0.06687			
14 8 7 113	8 6 1	242271.149	242271.32330	-0.17430			
14 8 6 113	8 5 1	242271.149	242271.32333	--0.17433			
14 7 8 113	7 7 1	242349.842	242350.00361	-0.16161			
14 7 7 113	7 6 1	242349.842	242350.00602	-0.16402			
1 4 1 1 3 0 1 3	1 1 2 0	242429.099	242428.62647	0.47253			
1 4 1 1 4 0 1 3	1 1 3 0	242429.099	242428.62647	0.47253			
1 4 1 0 4 0 1 3	1 0 3 0	242429.891	242430.30199	-0.41099			
1 4 1 0 5 0 1 3	1 0 4 0	242429.891	242430.301.99	-0.41099			
1 4 1 2 2 0 1 3	1 2 1 0	242434.782	242434.17391	0.60809			
1 4 1 2 3 0 1 3	1 2 2 0	242434.782	242434.17391	0.60809			
14 9 5 013	9 4 0	242442.980	242442.16473	0.81527			

TABLE I - *Continued*

J'Ka'Kc'TS'	J"Ka"Kc"TS"	Obs.	Freq. (MHz)	Calc.	Freq. (MHz)	Obs-Calc (MHz)	Ref.
14 9 6 013	9 5 0	242442.980	242442.16473	0.81527			
14 13 1 0 1	3 1 3 0 0	242445.208	242445.92122	-0.71322			
1 4 1 3 2 0 1	3 1 3 1 0	242445.208	242445.92122	-0.71322			
1.4 8 7 013	8 6 0	242470.119	242469.95867	0.16033			
14 8 6 013	8 5 0	242470.119	242469.95869	0.16031			
14 6 9 113	6 8 1	242475.584	242475.55329	0.03071			
14 6 8 113	6 7 1	242475.584	242475.72882	-0.14482			
14 7 8 013	7 7 0	242524.208	242524.30939	-0.10139			
1 4 7 7 0 1	3 7 6 0	242524.208	242524.31204	-0.10404			
14 6 9 013	6 8 0	242625.693	242625.89274	-0.19974			
14 6 8 013	6 7 0	242625.693	242626.08360	-0.39060			
1 4 5 1 0 1 1	3 5 9 I	242685.010	242685.05841	-0.04841			
14 5 9 113	5 8 1	242693.030	242693.08638	-0.05638			
1 4 3 1 2 1 1	3 3 1 1 1	242770.099	242770.10493	-0.00593			
1 4 5 1 0 0 1	3 5 9 0	242816.446	242816.43557	0.01043			
14 5 9 013	5 8 0	242825.099	242825.11254	-0.01354			
14 4 11 1 1 3	4 1 0 1	242995.960	242995.97560	-0.01560			
1 4 4 1 1 0 1	3 4 1 0 0	243120.317	243120.33644	-0.01944			
1 4 4 1 0 1 1	3 4 9 1 .	243206.515	243206.51211	0.00289			
1 4 4 1 0 0 1	3 4 9 0	243349.723	243349.73792	-0.01492			
1 2 3 1 0 0 1	1 2 1 0 1	244009.851	244009.92462	-0.07362			
1 4 1 1 3 0 1	3 0 1 3 1	244340.453	244340.41462	0.03838 *			
12 1 11 111	2 9 0	244587.467	244587.63537	-0.16837			
1 4 1 1 3 1 1	3 1 1 2 1	244633.950	244633.90922	0.04078			
14 3 11 1 1 3	3 1 0 1	245327.139	245327.06891	0.07009			
1 4 3 1 1 0 1	3 3 1 0 0	246414.762	246414.74233	0.01967			
1 5 1 1 5 0 1	4 1 1 4 0	247943.406	247943.33730	0.06870			
1 4 2 1 2 0 1	3 2 1 1 0	248463.614	248463.57290	0.04110			
15 0 1 5 0 1 4	0 1 4 0	248577.119	248577.05422	0.06478			
15 8 8 014	8 7 0	259814.446	259814.25331	0.19269			
15 8 7 014	8 6 0	259814.446	259814.25339	0.19261			
1 5 6 1 0 1 1	4 6 9 1	259852.27"/	259852.21922	0.05778			
15 6 9 114	6 8 1	259852.27"/	259852.60771	-0.33071			
1 5 6 1 0 0 1	4 6 9 0	260013.802	260013.95730	-0.15530			
15 6 9 014	6 8 0	260013.802	260014.37943	-0.57743			
1 5 1 1 4 0 1	4 1 1 3 0	260090.165	260090.21227	-0.04727			
1 5 5 1 1 1 1	4 5 1 0 1	260107.590	260107.63934	-0.04934			
1 5 5 1 0 1 1	4 5 9 1	260122.690	260122.78843	--0.09843			
1 5 3 1 3 0 1	4 3 1 2 0	260141.650	260141.65010	-0.00010			
1 6 1 1 6 0 1	5 1 1 5 0	264195.396	264195.30562	0.09038			
11 4 7 010	3 7 1	267718.566	267718.59927	-0.03327			
1 7 3 1 4 1 1	7 2 1 6 0	274715.342	274715.14259	0.19941			
11 4 8 1 11	3 8 0	275915.011	275915.23465	-0.22365			
1 4 2 1 2 1 1	4 1 1 4 0	276430.224	276430.19017	0.03383			
1 5 3 1 2 0 1	4 2 1 2 1	276443.441	276443.27500	0.16600			
1 6 1 1 5 1 1	5 1 1 4 1	276784.258	276783.66410	0.59390			
1 6 1 1 6 1 1	5 1 1 5 1	276784.285	276783.66410	0.62090			
1 6 1 0 6 1 1	5 1 0 5 1	276812.964	276812.29720	0.66680			

TABLE I - *Continued*

J'K'a'Kc'TS · J"K'a"Kc"TS"	Ohs.	Frea. (MHz)	Calc. Freq. (MHz)	Obs-Calc (MHz)	Ref.
1 . 6 1 0 7 1 1 5 1 0 6 1	276812.964	276812.29720	0.66680		
1 6 1 1 5 0 1 5 1 1 4 0	276816.838	276816.76628	0.07172		
16 9 7 115 9 6 1	276860.339	276860.49771	-0.15871		
1.6 9 8 115 9 7 1	276860.339	276860.49771	-0.15871		
16 8 9 115 8 8 1	276936.113	276936.34913	-0.23613		
16 8 8 115 8 7 1	276936.113	276936.34932	-0.23632		
1 6 7 1 0 1 1 5 7 9 1	277053.713	277053.94029	-0.22729		
16 7 9 115 7 8 1	277053.713	277053.95567	-0.24267		
1 6 1 1 5 0 1 5 1 1 . 4 0	277075.210	277074.23830	0.97170		
1 6 1 . 1 6 0 1 5 1 1 . 5 0	277075.210	277074.23830	0.97170		
1 6 1 0 6 0 1 5 1 0 5 0	277085.295	277086.09673	-0.80173		
1 6 1 0 7 0 1 5 1 0 6 0	277085.295	277086.09673	-0.80173		
1 6 1 4 2 0 1 5 1 4 1 0	277095.136	277095.49011	-0.35411		
1 6 1 4 3 0 1 5 1 4 2 0	277095.136	277095.49011	-0.35411		
16 9 7 015 9 6 0	277114.768	277113.04928	1.71872		
16 9 8 015 9 7 0	277114.768	277113.04928	1.71872		
1 6 1 5 1 0 1 5 1 5 0 0	277122.271	277121.91376	0.35724		
1 6 1 5 2 0 1 5 1 5 1 0	277122.271	277121.91376	0.35724		
1.0 4 7 110 3 7 0	277137.672	277137.82936	-0.15736		
16 8 9 015 8 8 0	277163.955	277163.69735	0.25765		
16 8 8 015 8 7 0	277163.955	277163.69756	0.25744		
1 6 6 1 1 1 1 5 6 1 0 1	277240.830	277240.71812	0.11188		
1 6 6 1 0 1 1 5 6 9 1	277241.144	277241.53009	-0.38609		
1 6 7 1 0 0 1 5 7 9 0	277253.700	277253.81233	-0.11233		
16 7 9 015 7 8 0	277253.700	277253.82921	-0.12921		
1 6 3 1 4 1 1 5 3 1 3 1	277278.966	277278.92546	0.04054		
1 6 3 1 4 0 1 5 3 1 3 0	277365.098	277365.06177	0.03623		
1 6 6 1 1 0 1 5 6 1 0 0	277413.498	277413.96336	-0.46536		
1 6 6 1 0 0 1 5 6 9 0	277414.313	277414.84499	-0.53199		
1 6 5 1 2 1 1 5 5 1 1 1	277547.190	277547.20233	-0.01233		
16 5 11 1 1 5 5 1 0 1	277574.501	277574.51930	-0.01830		
1 6 5 1 2 0 1 5 5 1 1 0	277700.231	277700.14485	0.08615		
1 . 6 5 1 1 0 1 5 5 1 0 0	277729.722	277729.64083	0.08117		
1 6 4 1 3 1 1 5 4 1 2 1	277926.479	277926.59568	-0.11668		
9 4 6 1 9 3 6 0	277978.614	277978.72881	-0.11481		
1 6 1 1 5 1 1 5 1 1 4 1	278042.263	278042.18501	0.07799		
1 6 4 1 3 0 1 5 4 1 2 0	278068.810	278068.79952	0.01048		
1 . 9 3 1 6 1 1 8 4 1 4 0	278207.572	278206.1.7077	1.40123		
1 2 4 8 1 1 2 3 1 0 0	278421.321	278421.40416	-0.08316		
1 6 4 1 2 1 1 5 4 1 1 1	278453.016	278453.23452	-0.21852		
11 4 7 111 3 9 0	278459.138	278459.20937	-0.07137		
1 3 4 9 1 1 3 3 1 1 0	278532.296	278532.38358	-0.08758		
3 3 0 1 2 2 0 0	278542.438	278542.25907	0.17893		
8 4 5 1 8 3 5 0	278549.382	278549.47560	-0.09360		
3 3 1 1 2 2 1 0	278577.168	278577.11091	0.05709		
10 4 6 110 3 8 0	278585.834	278585.93343	-0.09943		
1 6 4 1 2 0 1 5 4 1 1 0	278642.994	278643.01891	-0.02491		
2 1 2 2 0 1 2 0 3 1 8 0	278136.156	278735.68652	0.46948		

TABLE I - *Continued*

J'Ka'Kc'TS'	J"Ka"Kc"TS"	Obs .	Freq.	Calc.	Freq.	Obs-Calc	Ref.
		(MHz)		(MHz)		(MHz)	
9 4 5 1 9 3 7 0		278756.149	278"156.1.8769	-0.03869			
1 4 4 1 0 1 1 4 3 1 2 0		278868.251	278868.32218	-0.07118			
7 4 4 1 7 3 4 0		278931.399	278931.47617	-0.07717			
8 4 4 1 8 3 6 0		278937.211	278937.26571	-0.05471			
7 4 3 1 7 3 5 0		279107.358	279107.36525	-0.00725			
6 4 3 1 6 3 3 0		279183.485	279183.55442	-0.06942			
6 4 2 1 6 3 4 0		279253.815	279253.76943	0.04557			
5 4 2 1 5 3 2 0		279347.612	279347.59612	0.01588			
6 6 0 0 5 5 0 1		279354.992	279354.64247	0.34953			
6 6 1 055 1 1		279354.992	279354.64264	0.34936			
5 4 1 1 5 3 3 0		279371..009	279370.95754	0.05146			
4 4 1 1 4 3 1 0		279452.910	279452.84520	0.06480			
4 4 0 1 4 3 2 0		279458.767	279458.67572	0.09128			
15 4 11 1 15 313 0		279523.450	279523.47676	-0.02676			
17 1 17 016 1 16 0		280428.459	280428.32466	0.13434			
17 1 17 116 1 16 1		280521.485	280521.39217	0.09283			
16 4 12 1 16 3 14 0		280611.376	280611.64951	-0.27351			
17 0 17 0 16 0 16 0		280788.955	280788.83833	0.11667			
17 0 17 1 16 0 16 1		280936.369	280936.28966	0.07934			
16 3 13 1 15 3 12 1		281708.862	281708.70104	0.16096			
17 4 13 1 17 3 15 0		282266.910	282266.95449	-0.04449			
9 54 0 84 4 1		282834.775	282834.59916	0.17584			
9 5 5 0 8 4 5 1		282840.115	282840.02162	0.09338			
16 2 14 015 2 13 0		283136.475	283136.40124	0.07376			
8 1 7 1 7 0 7 0		283243.086	283243.18444	-0.09844			
16 214 1 15 3 12 0		283281.123	283281.06427	0.05873	*		
17 2 15 016 1 15 1		283690.684	283690.42325	0.26075			
14 3 12 0 13 2 12 1		283823.928	283824.01334	-0.08534			
12 4 8 011 3 8 1		284420.291	284420.32016	-0.02916			
18 4 14 1 18 316 0		284643.524	284643.43344	0.09056			
6 2 5 1 5 1 5 0		286080.933	286080.88970	0.04330			
12 4 9 011 3 9 1		286252.847	286252.80470	0.04230			
15 1 14 1 14 2 12 0		286528.225	286528.33948	-0.11448			
18 315 1 18 2 17 0		287028.398	287028.00939	0.38861			
23 2 21 023 1 23 1		287707.708	28"1707.92529	-0.21729			
19 4 15 1 19 3 17 0		287913.320	287913.02687	0.29313			
7 2 5 1 6 1 5 0		288022.998	288023.05850	-0.06050			
17 3 14 0 16 2 14 1		288699.64?	288699.51091	0.13109	*		
17 2 16 016 2 15 0		289459.939	289459.80225	0.13675			
17 2 16 116 2 15 1		289820.642	289820.67740	-0.03540			
22 320 1 21 4 18 0		290199.631	290199.52808	0.10292			
2 0 4 1 6 1 2 0 3 1 8 0		292261.825	292261.33076	0.49424			
1 7 1 1 6 0 1 6 1 1 5 0		293094.388	293094.30109	0.08691			
1 5 2 1 3 1 1 5 1 1 5 0		293716.890	293716.86532	0.02468			
1 7 1 1 6 1 1 6 1 1 5 1		294090.49"/	294090.32450	0.17250			
17 11 7 1 1 6 1 1 6 1		294090.497	294090.32450	0.17250			
1 7 1 0 7 1 1 6 1 0 6 1		294127.1"14	294126.37632	0.79768			
1 7 1 0 8 1 1 6 1 0 7 1		294127.174	294126.37632	0.79768			

TABLE 1- *Continued*

J'Ka'Kc'TS'	J"Ka"Kc"TS"	Obs. Freq. (MHz)	Calc. Freq. (MHz)	Obs-Calc (MHz)	Ref.
17 9 9	116 9 8 1	294185.132	294185.33709	-0.20509	
17 9 8	116 9 7 1	294185.132	294185.33710	-0.20510	
17 8 1 0 1 1	6 8 9 1	294276.594	294276.89526	-0.30126	
17 0 9	116 8 8 1	294276.594	294276.89578	-0.30178	
1 7 1 0 7 0 1 6 1 0 6 0		294416.345	294417.32873	-0.98373	
1 7 1 0 8 0 1 6 1 0 7 0		294416.345	294417.32873	-0.98373	
1 7 7 1 1 1 1 6 7 1 0 1		294417.831	294418.06168	-0.23068	
1 7 7 1 0 1 1 6 7 9 1		294417.831	294418.09692	-0.26592	
17 3 1 5 1 1 6 3 1 4 1		294460.377	294460.33396	0.04304	
1 6 2 1 4 1 1 5 2 1 3 1		294494.444	294494.32683	0.11717 *	
1 7 8 1 0 0 1 6 8 9 0		294518.954	294518.63152	0.32248	
17 8 9 0 1 6 8 8 0		294518.954	294518.63210	0.32190	
1 7 3 1 5 0 1 6 3 1 4 0		294533.258	294533.20688	0.05112	
1 7 7 1 1 0 1 6 7 1 0 0		294630.647	294630.78229	-0.13529	
1 7 7 1 0 0 1 6 7 9 0		294630.647	294630.82092	-0.17392	
17 6 12 1 1 6 6 1 1 1		294641.882	294641.84402	0.03798	
1 7 6 1 1 1 1 6 6 1 0 1		294643.531	294643.45886	0.07214	
1 7 6 1 2 0 1 6 6 1 1 0		294826.033	294826.70107	-0.66807	
17 6 11 0 1 6 6 1 0 0		294827.796	294828.45312	-0.65712	
1 7 5 1 3 1 1 6 5 1 2 1		295004.020	295004.01434	0.00566	
) 7 5 1 2 1 1 6 5 1 1 1		295051.349	295051.34771	0.00129	
1 7 5 1 3 0 1 6 5 ,12 0		295168.020	295167.90809	0.11191	
1 7 5 1 2 0 1 6 5 1 1 0		295219.112	295218.98855	0.12345	
) 7 4 14 1 1 6 4 1 3 1		295397.587	295397.53397	0.05303	
1 7 4 1 4 0 1 6 4 1 3 0		295547.097	295547.14371	--0.04671	
4 3 1 1 3 2 1 0		295775.698	295775.61129	0.08671	
1 5 2 1 4 0 1 4 1 1 4 1		295852.063	295851.88274	0.18026	
4 3 2 1 3 2 2 0		295948.758	295948.63825	0.11975	
1 7 4 1 3 1 1 6 4 1 2 1		296188.809	296188.51185	0.29715	
1 7 4 1 3 0 1 6 4 1 2 0		296410.011	296410.01466	-0.00366	
2 3 2 2 2 1 2 2 3 2 0 0		296596.752	296596.58066	0.17134	
1 8 1 1 8 0 1 7 1 1 7 0		296645.828	296645.67436	0.15364	
7 6 1 0 6 5 1 1		296721.007	296720.71104	0.29596	
7 6 2 0 6 5 2 1		296721.007	296720.71287	0.29413	
1 8 1 1 8 1 1 7 1 1 7 1		296724.756	296724.66036	0.09564	
1 8 0 1 8 0 1 7 0 1 7 0		296913.286	296913.14546	0.14054	
1 8 0 1 8 1 1 7 0 1 7 1		297023.174	29"1023.08479	0.08921	
2 1 4 1 7 1 2 1 3 1 9 0		297881.279	297880.54004	0.73896	
1 6 1 1 5 1 1 5 2 1 . 3 0		298546.402	298546.50373	-0.10173	
1 7 2 1 5 0 1 6 2 1 4 0		299100.615	299100.52575	0.08925	
1 7 3 1 4 1 1 6 3 1 3 1		300001.296	300001.04367	0.25233	
1 0 5 5 0 9 4 5 1		300163.670	300163.52755	0.14245	
1 0 5 6 0 9 4 6 1		300177.556	300177.51584	0.04016	
17 3 1 4 0 1 6 3 1 3 0		300447.984	300447.89058	0.09342 *	
13 4 9 0 12 3 9 1		300833.750	300833.76261	-0.01261	
1 9 3 1 6 1 1 9 2 1 8 0		301134.263	301133.64069	0.62231	
1 7 2 1 5 1 1 6 2 1 4 1		301362.624	301362.53836	0.08564 *	
1 6 1 1 5 0 1 5 0 1 . 5 1		302546.43'1	302546.20722	0.22978	

TABLE I - *Continued*

J' K _a "	K _c "	TS'	J" K _a "	K _c "	TS"	Obs.	Freq. (MHz)	Calc.	Freq. (MHz)	Obs-Calc (MHz)	Ref.	
1	8	9	1	0	1	1	7	9	9	1	-0.27520	
18	9	9	117	9	8	1	311513.702	311513.97720	-0.27522			
1	8	3	1	6	1	1	7	3	15	1	0.11043	
1	8	8	1	1	1	1	7	8	1	0	1	-0.35385
18	8	10	1	17	8	9	1	311622.903	311623.25685	-0.35516		
1	8	3	1	6	0	1	7	3	1	5	0	0.05621
1	8	1	0	8	0	1	7	1	0	7	0	-1.11013
1	8	1	0	9	0	1	7	1	0	8	0	-1.11013
18	7	12	1	1	7	7	1	1	1	1	311790.683	311791.00361
1	8	7	1	1	1	1	7	7	1	0	1	-0.39716
18	8	11	0	1	7	8	1	0	0	3118"19.786	311879.39873	
1	8	8	1	0	0	1	7	8	9	0	3118"19.786	0.38583
1	8	7	1	2	0	1	7	7	1	1	312016.431	312016.61129
1	8	7	1	1	0	1	7	7	1	0	312016.431	-0.18029
1	8	6	1	3	1	1	7	6	1	2	1	-0.26411
1	8	6	1	2	1	1	7	6	1	1	312056.487	312056.37191
1	8	6	1	3	0	1	7	6	1	2	0	0.09217
1	8	6	1	2	0	1	7	6	1	1	312252.054	312252.93750
1	8	6	1	2	0	1	7	6	1	1	0	-0.88350
1	8	5	1	4	1	1	7	5	13	1	312255.371	312256.27093
1	8	5	1	3	1	1	7	5	12	1	312477.928	312477.91356
1	8	5	1	4	0	1	7	5	1	3	0	0.01444
1	8	5	1	3	0	1	7	5	1	2	0	0.03082
1	8	5	1	4	0	1	7	5	1	3	0	0.17929
1	8	5	1	3	0	1	7	5	1	2	0	312738.303
1	9	1	1	9	0	1	8	1	1	8	0	312738.14186
1	8	4	1	5	1	1	7	4	1	4	1	0.15550
5	3	2	1	4	2	2	0	312864.1.96	312864.13536	0.06064		
1	9	1	1	9	1	1	8	1	1	8	1	0.10306
1	8	1	1	7	1	1	7	2	1	5	0	312922.204
1	8	4	1	5	0	1	7	4	1	4	0	312922.11012
1	9	0	1	9	0	1	8	0	1	8	0	0.09388
1	7	2	1	5	1	1	6	3	1	3	0	313001.806
1	9	0	1	9	1	1	8	0	1	8	1	0.03692
5	3	3	1	4	2	3	0	313019.627	313019.64828	-0.02128		
1	8	4	1	5	0	1	7	5	1	2	0	313047.014
1	7	2	1	5	1	1	6	3	1	3	0	313046.86483
1	9	0	1	9	0	1	8	0	1	8	0	0.14917
1	7	2	1	5	1	1	6	3	1	3	0	313110.984
1	9	0	1	9	1	1	8	0	1	8	1	0.06597
5	3	3	1	4	2	3	0	313110.91803	*			
1	8	2	1	6	0	1	7	1	1	6	1	313138.14376
18	4	14	1	17	4	1	3	1	314016.288	0.10124		
8	6	2	0	7	5	2	1	314093.24"/	314093.08250	0.36958		
8	6	3	0	7	5	3	1	314093.24"/	314093.09341	0.16450		
1	8	4	1	4	0	1	7	4	1	3	0	0.15359
1	4	4	1	0	0	1	3	3	1	0	1	-0.03924
1	8	3	1	5	0	1	7	3	1	4	0	316888.72-/
1	8	3	1	5	1	1	7	3	1	4	1	316888.81177
1	8	2	1	6	1	1	7	2	1	5	1	0.08493
1	4	4	1	1	0	1	3	3	1	1	1	318262.673
1	9	3	1	6	0	1	8	2	1	6	1	318262.58807
1	9	2	1	8	0	1	8	2	1	7	0	318305.153
1	9	5	1	5	1	1	9	4	1	5	0	318304.83491
1	8	2	1	6	1	1	7	2	1	5	1	0.31809
1	4	4	1	1	0	1	3	3	1	1	1	319168.372
1	9	3	1	6	0	1	8	2	1	6	1	319168.24387
1	9	2	1	8	1	1	8	2	1	6	0	0.12813
1	4	4	1	1	0	1	3	3	1	1	1	321461.359
1	9	3	1	6	0	1	8	2	1	6	1	321461.29473
1	9	2	1	8	0	1	8	2	1	7	0	0.06427
1	9	3	1	6	0	1	8	2	1	6	1	322461.310
1	9	2	1	8	0	1	8	2	1	7	0	322466.533
1	9	5	1	5	1	1	9	4	1	5	0	322617.898
1	9	1	1	8	0	1	8	1	1	7	0	325203.139
1	9	2	1	8	1	1	8	2	1	6	0	325812.426
1	9	1	1	8	1	1	8	1	1	7	1	326845.257

TABLE I - *Continued*

J' K _a ' K _c ' TS'	J" K _a " K _c " TS"	Ohs. Freq. (MHz)	Cal. Freq. (MHz)	Obs-Calc (MHz)	Ref.
8 2 7 1 7 1 7 0		327671.010	327670.94543	0.06457	
1 9 1 0 9 0 1 8 1 0 8 0		329085.881	329087.14917	-1.26817	
1 9 1 0 1 0 0 1 8 1 0 9 0		329085.881	329087.14917	-1..26817	
2 0 1 2 0 1 1 9 1 1 9 1		329112.286	329112.21102	0.07498	
1 9 7 1 3 1 1 8 7 1 2 1		3291"/ 2.960	329173.31571	-0.35571	
1 9 7 1 2 1 1 8 7 1 1 1		329172.960	329173.47438	-0.51438	
2 0 0 2 0 0 1 9 0 1 9 0		329187.752	329187.62614	0.12586	
1 9 7 1 3 0 1 8 7 1 2 0		329411.594	329411.84348	-0.24948	
1 9 7 1 2 0 1 8 7 1 1 0		329411.594	329412.01703	-0.42303	
1 9 6 1 4 1 1 8 6 1 3 1		329485.248	329485.03979	0.20821	
1 9 6 1 3 1 1 8 6 1 2 1		329490.891	329490.67354	0.21746	
1 9 5 1 5 0 1 8 5 1 4 0		330154.099	330153.88019	0.21881	
1 9 2 1 7 0 1 8 2 1 7 1		331228.871	331228.74651	0.12449	
11 5 7 111 4 7 0		331648.822	331649.10991	-0.28791	
10 1 9 1 90 9 0		331880.352	331880.43055	-0.07855	
2 0 2 1 9 0 1 9 2 1 8 0		338887.931	338887.83890	0.09210	
2 0 2 1 9 1 1 9 2 1 8 1		339461.788	339461..86191	-0.07391	
2 1 1 2 1 0 2 0 1 2 0 0		345229.248	345229.05645	0.19155	
1 7 2 1 6 0 1 6 1 1 6 1		345675.752	345677.36220	-1.61020	
21 4 17 1 2 0 4 1 6 1		368164.657	368164.29968	0.35732	
2 1 4 1 7 0 2 0 4 1 6 0		368600.073	368600.30300	-0.23000	
20 2 18 1 1 9 3 1 6 0		368697.041	368696.85362	0.18738 *	
1 8 3 1 6 0 1 7 2 1 6 1		368793.521	368793.50046	0.02054	
2 1 2 1 9 0 2 0 2 1 8 0		369095.470	369095.31733	0.15267	
14 5 9 0134 9 1		369119.518	369119.40022	0.11778	
1 4 5 1 0 0 1 3 4 1 0 1		369371.712	369371.58125	0.13075	
2 1 2 1 9 1 2 0 3 1 7 0		370704.253	370704.16853	0.08447 *	
2 2 2 2 0 1 2 1 3 1 8 0		370910.178	370910.16680	0.01120	
1 0 2 9 1 9 1 9 0		371439.570	371439.50405	0.06595	
22 2 21 0 2 1 2 2 0 0		371592.623	371592.68444	-0.06144	
2 2 2 2 1 1 2 1 2 2 0 1		371754.201	371754.43542	-0.23442	
21 3 1 8 0 2 0 2 1 8 1		371994.814	371994.69257	0.12143 *	
2 1 3 1 8 1 2 0 3 1 7 1		372824.240	372823.77610	0.46390	
2 2 1 2 1 0 2 1 1 2 0 0		373079.996	373079.99266	0.00334	
2 2 1 2 1 1 2 1 1 2 0 1		373394.675	373394.71442	-0.03942	
1 2 2 1 0 1 1 1 1 1 0 0		375101.696	375101.83332	-0.13732	
2 0 2 1 8 0 1 9 1 1 8 1		375201.682	375201.93756	-0.25556	
1 7 4 1 4 0 1 6 3 1 4 1		375572.909	375572.90695	0.00205	
2 3 6 1 8 1 2 3 5 1 8 0		376474.922	376473.98155	0.94045	
1 8 4 1 4 0 1 7 3 1 4 1		376669.899	376670.69224	-0.79324	
2 3 1 2 3 0 2 2 1 2 2 0		377576.576	377578.20169	-1.62569	
2 3 0 2 3 0 2 2 0 2 2 0		377632.021	377632.20737	-0.18637	
2 3 1 2 3 1 2 2 1 2 2 1		377643.013	377642.95384	0.05916	
2 3 0 2 3 1 2 2 0 2 2 1		377-/01.17'7	377701.09477	0.08223	
24 6 18 1 2 4 5 2 0 0		377814.411	377813.07609	1.33491	
9 3 6 1 8 2 6 0		378438.196	378438.13978	0.05622	
23 6 17 1 2 3 5 1 9 0		378699.471	378698.92080	0.55020	
2 2 3 2 0 0 2 1 3 1 9 0		379367.994	379367.96017	0.03383	

TABLE I - *Continued*

J' Ka' Kc' TS	J" Ka" Kc" TS"	Ohs. Freq. (MHz)	Calc. Freq. (MHz)	Obs-Calc (MHz)	Ref.
8 2 7 1 7 1 7 0		327671.010	327670.94543	0.06457	
1 9 1 0 9 0 1 8 1 0 8 0		329085.881	329087.14917	-1.26817	
2 2 6 1 6 1 2 2 5 1 8 0		379577.142	379577.08390	0.05810	
9 7 2 0 8 6 2 1		379963.661	379963.18477	0.47623	
9 7 3 0 8 6 3 1		379963.661	379963.18498	0.47602	
21 6 15 1 21 5 17 0		380421.546	380421.71054	-0.16454	
20 6 15 1 20 5 15 0		380638.452	380638.83160	-0.37960	
22 9 14 1 21 9 13 1		3808"/ 0.647	380870.97627	-0.32927	
22 9 13 1 21 9 12 1		380870.647	380870.97686	-0.32986	
22 8 15 1 21 8 14 1		381073.355	381073.93576	-0.58076	
22 8 14 121 8 13 1		381073.355	381073.96610	-0.61110	
20 6 14 1 20 5 16 0		381214.825	381215.15127	-0.32627	
20 6 14 1 20 5 16 0		381214.825	381215.15127	-0.32627	
22 7 16 1 21 7 15 1		381381.456	381387.10383	-0.64783	
22 7 15 121 7 14 1		381381.619	381383.22380	-1.60480	
2 2 8 1 5 0 2 1 8 1 4 0		381388.361	381387.78663	0.57437	
2 2 8 1 4 0 2 1 8 1 3 0		381388.361	381387.82009	0.54091	
19 6 14 1 1 9 5 1 4 0		381597.134	381597.45346	-0.31946	
2 2 7 1 6 0 2 1 7 15 0		381658.609	381659.50838	-0.89938	
2 2 7 1 5 0 2 1 7 14 0		381659.888	381660.72912	-0.84112	
9 3 7 1 8 1 8 1		381744.588	381744.44807	0.13993	
22 6 17 1 2 1 6 1 6 1		381862.972	381862.08438	0.88762	
2 2 6 1 6 1 2 1 6 1 5 1		381891.519	381890.62739	0.89161	
1 9 6 1 3 1 1 9 5 1 5 0		381946.068	381946.38415	-0.31615	
1 8 6 1 3 1 1 8 5 1 3 0		382404.197	382404.52679	-0.32979	
2 2 5 1 8 1 2 1 5 1 7 1		382519.683	382519.52839	0.15461	
2 2 4 1 9 1 2 1 4 1 8 1		382535.072	382534.95139	0.12061	
18 6 12 1 1 8 5 1 4 0		382609.237	382609.59080	-0.35380	
2 2 4 1 9 0 2 1 4 1 8 0		382688.714	382688.87620	-0.16220	
2 2 5 1 8 0 2 1 5 1 7 0		382735.884	382735.25403	0.62997	
2 2 5 1 7 1 2 1 5 1 6 1		382982.364	382982.12029	0.24371	
1 7 6 1 2 1 1 7 5 1 2 0		383086.021	383086.29674	-0.27574	
6 4 2 1 5 3 2 0		383190.973	383190.961.91	0.01109	
17 6 11 1 1 7 5 1 3 0		383202.639	383202.90668	-0.26768	
6 4 3 1 5 3 3 0		383213.621	383213.70977	-0.08877	
2 2 5 1 7 0 2 1 5 1 6 0		383233.259	383232.73199	0.52701	
12 6 6 0 1 1 5 6 1		383591.612	383591.68794	-0.07594	
12 6 7 0 1 1 5 7 1		383592.854	383592.98324	-0.12924	
16 6 11 1 1 6 5 1 1 0		383663.213	383663.44128	-0.22828	
1 6 6 1 0 1 1 6 5 1 2 0		383727.148	383727.35590	-0.20790	
1 5 6 1 0 1 1 5 5 1 0 0		384152.214	384152.36398	-0.14998	
1 5 6 9 1 1 5 5 1 1 0		384185.86-/	384185.97067	-0.10367	
27 4 23 1 2 6 5 2 1 0		384379.359	384379.84410	-0.48510	
12 1 1 1 1 1 1 0 1 1 0		384460.109	384460.15147	-0.04247	
14 6 9 114 5 9 0		384566.168	384566.23368	-0.06568	
1 4 6 8 1 1 4 5 1 0 0		384583.062	384583.08592	-0.02392	
2 3 2 2 1 1 2 2 3 1 9 0		384676.986	384676.87169	0.11431	
13 6 8 113 5 8 0		384915.813	384915.79293	0.02007	

TABLE I - *Continued*

J'	K_a	K_c	'TS'	$J''K_a''K_c''TS''$	Obs.	Freq. (MHz)	Cal. c. (MHz)	Freq. (MHz)	Obs-Calc (MHz)	Ref.
13	6	7	113	5 9 0	384923.814	384923.79267	0.02133			
12	6	7	112	5 7 0	385210.064	385209.96797	0.09603			
12	6	6	112	5 8 0	385213.596	385213.52(173)	0.06727			
11	6	6	111	5 6 0	385456.416	385456.31569	0.10031			
11	6	5	111	5 7 0	385457.883	385457.78329	0.09971			
10	6	5	110	5 5 0	385661.710	385661.34156	0.36844			
10	6	4	110	5 6 0	385661.710	385661.89220	--0.18220			
2	2	2	2 0	0 2 1 2 1 9 0	385796.610	385796.38585	0.22415			
9	6	4	1 9	5 4 0	385830.888	385830.71864	0.16936			
9	6	3	1 9	5 5 0	385830.888	385830.90223	-0.01423			
8	6	3	1 8	5 3 0	385969.534	385969.43331	0.10069			
8	6	2	1 8	5 4 0	385969.534	385969.48576	0.04824			
7	6	2	1 7	5 2 0	386081.938	386081.87827	0.05973			
7	6	1	1 7	5 3 0	386081.938	386081..89037	0.04763			
6	6	1	1 6	5 1 0	386171.905	386171.90917	-0.00417			
6	6	0	1 6	5 2 0	386171.905	386171.91118	-"0.00618			
15	5	10	014	4 10 1	386179.108	386178.97703	0.13097			
9	3	7	1 8	2 7 0	386381.522	386381.49133	0.03067			
22	4	18	121	4 17 1	386447.061	386446.67799	0.38301			
15	5	11	014	4 11 1	386625.511	386625.32861	0.18239			
22	4	18	021	4 17 0	386953.565	386953.84603	-0.28103			
21	3	18	020	3 17 0	387122.262	387122.04870	0.21330 *			
19	1	18	018	0 18 1	387163.680	387163.41744	0.26256			
22	2	20	1 21	2 19 1	387328.208	387328.04697	0.16103			
23	2	22	022	2 21 0	387886.682	387886.84596	-0.16396			
23	2	22	1 22	2 21 1	388019.539	388019.50928	0.02972			
23	1	22	022	1 21 0	389058.705	389058.75942	-0.05442			
23	1	22	122	1 21 1	389299.117	389299.08325	0.03375			
22	3	19	0 21	3 1 8 0	389732.091	389732.01171	0.07929			
19	4	15	018	3 15 1	390623.184	390624.33863	-1.15463			
22	3	19	1 21	3 18 1	390745.476	390745.00564	0.47036			
24	1	24	023	1 23 0	393744.934	393744.15666	0.77734			
24	0	24	0 23	0 23 0	393783.005	393782.77798	0.22702			
10	3	7	1 92	7 0	393800.939	393800.85542	0.08358			
24	1	24	1 23	1 23 1	393808.985	393808.90826	0.07674			
24	024	1	23 0	23 1	393850.481	393850.43052	0.05048			
11	2	10	1 10	1 10 0	394128.058	394127.91491	0.14309			
1	8	4	1 5 0	1 7 3 1 5 1	394132.204	394132.22127	-0.01727			
2	3	3	2 1 0	2 2 3 2 0 0	396117.14"1	396117.15149	-0.00449			
2	3	3	2 1 1	2 2 3 2 0 1	396629.777	396630.52688	-0.74968			
2	4	2	2 2 1	2 3 3 2 0 0	396733.643	396733.74389	-0.10089			
1	9	2	1 8 0	1 8 1 1 8 1	396890.001.	396889.67459	0.32641			
1	0	7	3 0 9	6 3 1	397370.263	397369.84146	0.42154			
10	7	4	09	6 4 1	397370.263	397369.84251	0.42049			
2	3	9	1 5 1	2 2 9 1 4 1	398221.693	398221.96332	-0.27032			
2	3	9	1 4 1	2 2 9 1 3 1	398221.693	398221.96463	-0.27163			
2	3	8	1 6 1	2 2 8 1 5 1	398454.146	398454.74140	--0.59540			
2	3	8	1 5 1	2 2 8 1 4 1	398454.146	398454.80171	--0.65571			

TABLE I - *Continued*

J'Ka'Kc'TS'	J"Ka"Kc"TS"	Obs (MHz)	Freq. (MHz)	Calc. (MHz)	Freq. (MHz)	Obs-Calc (MHz)	Ref.
2 3 8 1 6 0 2 2 8 1 5 0		398783.607	398783.00882	0.59818			
2 3 8 1 5 0 2 2 8 1 4 0		398783.607	398783.07523	0.53177			
2 3 7 1 7 1 2 2 7 1 6 1		398806.834	398807.56040	-0.72640			
2 3 7 1 6 1 2 2 7 1 5 1		398808.848	398809.57341	-0.72541			
2 3 7 1 7 0 2 2 7 1 6 0		399096.768	399097.92344	-1.15544			
2 3 7 1 6 0 2 2 7 1 5 0		399098.955	399100.11477	-1.15977			
2 3 6 1 8 1 2 2 6 1 7 1		399354.164	399352.81030	1.35370			
2 3 6 1 7 1 2 2 6 1 6 1		399400.543	399399.20503	1.33797			
2 3 4 2 0 1 2 2 4 1 9 1		399863.613	399863.49676	0.11624			
2 3 4 2 0 0 2 2 4 1 9 0		400006.823	400007.01183	-0.18883			
2 3 5 1 9 1 2 2 5 1 8 1		400053.475	400053.25334	0.22166			
2 3 5 1 9 0 2 2 5 1 8 0		400278.247	400277.36813	0.87887			
7 4 3 1 6 3 3 3 0		400366.921	400366.96758	-0.04658			
7 4 4 1 6 3 4 0		400434.694	400434.79944	-0.10544			
2 3 5 1 8 1 2 2 5 1 7 1		400729.369	400729.03962	0.32938			
13 6 7 0 1 2 5 7 1		400950.217	400950.58455	-0.36755			
13 6 8 0 1 2 5 8 1		400953.435	400953.70740	-0.27240			
2 3 5 1 8 0 2 2 5 1 7 0		401004.192	401003.48608	0.70592			
1 0 3 8 1 9 2 8 0		401639.423	401639.24623	0.17677			
2 3 2 2 1 0 2 2 2 2 0 0		402185.370	402184.95628	0.41372			
21 2 19 0 2 0 1 1 9 1		402353.739	402353.89199	-0.15299			
1 6 5 1 1 0 1 5 4 1 1 1		403111.962	403111.81317	0.14883			
23 2 21 1 2 2 2 2 0 1		403498.908	403498.71660	0.19140			
2 4 8 1 7 1 2 3 8 1 6 1		415842.943	415843.56324	-0.62024			
2 4 8 1 6 1 2 3 8 1 5 1		415842.943	415843.67927	-0.73627			
2 4 8 1 7 0 2 3 8 1 6 0		416186.763	416186.22502	0.53798			
2 4 8 1 6 0 2 3 8 1 5 0		416186.763	416186.35261	0.41039			
2 4 7 1 8 1 2 3 7 1 7 1		416244.411	416245.23588	-0.82488			
24 7 17 1 2 3 7 1 6 1		416247.936	416248.75508	-0.81908			
2 4 7 1 8 0 2 3 7 1 7 0		416546.973	416548.52903	-1.55603			
2 4 7 1 7 0 2 3 7 1 6 0		416550.788	416552.35480	--1.56680			
2 4 4 2 1 1 2 3 4 2 0 1		417141.695	417141.55155	0.14345			
24 4 21 0 2 3 4 2 0 0		417268.203	417268.43920	-0.23620			
1 2 2 1 1 1 1 1 1 1 0		417335.616	417335.51129	0.10471			
2 4 5 2 0 1 2 3 5 1 9 1		417588.055	417587.80294	0.25206			
2 4 5 2 0 0 2 3 5 1 9 0		417820.172	417818.98411	1.18789			
1 4 2 1 2 1 1 3 1 1 2 0		418091.228	418091.23604	-0.00804			
14 6 8 0 1 3 5 8 1		418293.251	418293.76278	-0.51178			
14 6 9 0 1 3 5 9 1		418300.189	418300.73136	-0.54236			
2 4 2 2 2 0 2 3 2 2 1 0		418357.377	418356.54918	0.82782			
2 4 5 1 9 1 2 3 5 1 8 1		418553.785	418553.38843	0.39657			
2 4 5 1 9 0 2 3 5 1 8 0		418856.381	418855.48589	0.89511			
5 5 0 1 4 4 0 0		419283.879	419284.14231	-0.26331			
5 5 1 1 4 4 1 0		419283.879	419284.15453	-0.27553			
24 2 22 1 23 2 21 1		419393.606	419393.39765	0.20835			
1 7 5 1 2 0 1 6 4 1 2 1		419878.043	419877.56721	0.47579			
2 5 2 2 4 0 2 4 2 2 3 0		420383.801	420384.24423	-0.43723			
25 2 24 1 2 4 2 2 3 1		420497.073	420497.09912	-0.02612			

TABLE I - *Continued*

^J 'K _a 'K _c ' TS	^J "K _a "K _c " TS"	Obs.	Freq. (MHz)	Calc. (MHz)	Freq. (MHz)	Obs-Calc (MHz)	Ref.
11 3 9	110 2 9	0	420822.417	420822.27661	0.14039		
2 5 1 2 4 0 2 4 1 2 3 0			421084.733	421084.91755	-0.18455		
1 7 5 1 3 0 1 6 4 1 3 1			421109.552	421109.13465	0.41735		
2 5 1 2 4 1 2 4 1 2 3 1			421253.552	421253.56193	-0.00993		
2 0 2 1 9 0 1 9 1 1 9 1			422855.709	422855.40336	0.30564		
12 3 9 111 2 9 0			423448.149	423448.07551	0.07349		
2 4 4 2 0 0 2 3 4 1 9 0			423882.058	423882.45710	-0.39910		
2 6 1 2 6 0 2 5 1 2 5 0			426061.680	426061.75457	-0.07457		
2 6 0 2 6 0 2 5 0 2 5 0			426081.243	426081.29499	-0.05199		
2 4 3 2 1 1 2 3 3 2 0 1			426112.060	426111.74110	0.31890		
2 6 1 2 6 1 2 5 1 2 5 1			426126.044	42612".26840	-1.22440		
2 6 0 2 6 1 2 5 0 2 5 1			426147.676	426148.24603	-0.57003		
2 2 2 2 0 0 2 1 1 2 0 1			430573.743	430573.72185	0.02115		
1 2 7 5 0 1 1 6 5 1			432197.535	432197.23361	0.30139		
12 7 6 011 6 6 1			432197.535	432197.24772	0.28728		
2 0 4 1 7 0 1 9 3 1 7 1			432290.021	432290.29469	-0.27369		
2 8 1 2 8 0 2 7 1 . 2 7 0			458362.010	458362.28020	-0.27020		
2 8 0 2 8 0 2 7 0 2 7 0			4583"? 2.027	458372.04994	-0.02294		
2 8 1 2 8 1 2 7 1 . 2 7 1			458429.090	458429.15492	-0.06492		
2 8 0 2 8 1 2 7 0 2 7 1			458439.558	458439.63584	-0.07784		
2 3 2 2 1 0 2 2 1 . 2 1 1			459364.408	459363.96372	0.44428		
1 3 3 1 1 1 1 2 2 1 1 0			459798.058	459798.08596	-0.02796		
2 6 3 2 3 0 2 5 3 2 2 0			460065.262	460065.63657	-0.37457		
2 6 4 2 2 1 2 5 4 2 1 1			460218.301	460218.05215	0.24885		
2 6 4 2 2 0 2 5 4 2 1 0			460722.493	460723.00728	-0.51428		
2 6 3 2 3 1 2 5 3 2 2 1			460855.706	460855.81194	-0.10594		
2 7 3 2 5 0 2 6 3 2 4 0			462416.021	462415.62669	0.39431		
2 7 3 2 5 1 2 6 3 2 4 1			462691.944	462692.22688	-0.28288		
2 2 3 2 0 0 2 1 2 2 0 1			463176.666	463177.36404	-0.69804		
1 4 2 1 3 1 1 3 1 1 3 0			465227.149	465227.04869	0.10031		
2 7 2 2 5 1 2 6 2 2 4 1			466594.016	466593.84428	0.17172		
14 7 7 013 6 7 1			467028.018	467027.73169	0.28631		
14 7 8 013 6 8 1			467028.018	467027.84528	0.17272		
1 5 3 1 2 1 1 4 2 1 2 0			467671.063	467670.85586	0.20714		
2 7 9 1 9 1 2 6 9 1 8 1			467680.586	467679.93328	0.65272		
2 7 9 1 8 1 2 6 9 1 7 1			467680.586	467679.95514	0.63086		
11 4 7 110 3 7 0			467899.995	467900.13391	-0.13891		
2 7 4 2 4 1 2 6 4 2 3 1			468639.355	468639.38436	-0.02936		
2 0 5 1 5 0 1 9 4 1 5 1			468641.991	468641.51046	0.48054		
2 7 4 2 4 0 2 6 4 2 3 0			468647.113	468647.36030	-0.24730		
2 7 7 2 0 1 2 6 7 1 9 1			468652.020	468653.18309	-1.16309		
2 8 2 2 7 0 2 7 2 2 6 0			468966.086	468966.98699	-0.90099		
1 5 1 1 4 1 1 4 0 1 4 0			469023.807	469023.77928	0.02772		
28 2 27 1 27 2 2 6 1			469071.876	469071.96087	-0.08487		
11 4 8 110 3 8 0			469242.249	469242.35416	-0.10516		
2 8 1 2 7 0 2 7 1 2 6 0			469269.297	469269.19686	0.10014		
28 1 27 1 2 7 1 2 6 1			469396.062	469396.13172	-0.06972		
2 7 5 2 3 1 2 6 5 2 2 1		470133.730	4701.33.24168	0.48832			

TABLE I - *Continued*

J'Ka'Kc'TS'	J"Ka"Kc"TS"	Obs. Freq. (MHz)	Calc. Freq. (MHz)	Obs-Calc (MHz)	Ref.
11 3 9	110 2 9 0	420822.417	420822.27661	0.14039	
2 5 1 2 4 0 2 4	1 2 3 0	421.084.733	421084.91755	-0.18455	
2 2 1 2 1 0 2 1	0 2 1 1	470716.117	470715.99699	0.12001	
8 5 3 1 7 4 3 0		470998.970	470999.21323	-0.24323	
8 5 4 1 7 4 4 0		471000.968	471001.20372	-0.23572	
22 4 19 021 3 19 1		472034.064	472034.52182	-0.45782	
27 522 1 26 5 21 1		472613.669	472613.12016	0.54884	
20 516 0 19 4 16 1		473005.628	473004.65537	0.97263	
27 5 22 0 26 5 21 0		473026.626	473024.86274	1.76326	
29 1 29 0 28 1 2 8 0		474506.130	474506.50159	-0.37159	
29 0 29 0 28 0 28 0		474513.622	474513.38409	0.23791	
29 1 29 128 1 28 1		474574.058	474574.18929	-0.13129	
29 0 29 1 28 0 28 1		474581.427	474581.57077	-0.14377	
2 2 2 2 1 0 2 1 1 2 1 1		475302.130	475302.09818	0.03182	
2 7 3 2 4 0 2 6 3 2 3 0		477563.358	477564.47811	-1.12011	
2 7 3 2 4 1 2 6 3 2 3 1		477976.761	477977.07820	-0.31720	
2 7 4 2 3 1 2 6 4 2 2 1		478613.143	478612.57491	0.56809	
2 8 3 2 6 0 2 7 3 2 5 0		478835.862	478833."12336	2.13864	
2 7 4 2 3 0 2 6 4 2 2 0		478963.951	478964.58792	-0.63692	
2 8 3 2 6 1 2 7 3 2 5 1		479009.811	479009.96196	-0.15096	
1 7 3 1 4 0 1 6 1 1 5 0		479668.148	479668.25314	-0.10514	
1 4 3 1 2 1 1 3 2 1 2 0		479891.129	479891.20584	-0.07684	
2 8 2 2 6 1 2 7 2 2 5 1		482313.875	482313.72711	0.14789	
1 6 3 1 3 1 1 5 2 1 3 0		483355.843	483355.53615	0.30685	
12 4 8 111 3 8 0		484168.180	484168.38444	-0.20444	
2 1 5 1 6 0 2 0 4 1 6 1		4841.76.192	484175.63140	0.56060	
15 7 8 014 6 8 1		484437.508	484437.17453	0.33347	
15 7 9 014 6 9 1		484437.508	484437.45672	0.05128	
2 9 2 2 8 0 2 8 2 2 7 0		485129.966	485130.95448	-0.98848	
2 9 2 2 8 1 2 8 2 2 7 1		485234.551	485234.65709	-0.10609	
2 9 1 2 8 0 2 8 1 2 7 0		485357.122	485356.15456	0.96744	
2 9 1 2 8 1 2 8 1 2 7 1		485475.850	485475.97502	-0.12502	
2 8 4 2 5 0 2 7 4 2 4 0		485623.419	485623.65545	-0.23645	
2 8 4 2 5 1 2 7 4 2 4 1		485722.378	485722.54756	-0.16956	
2 8 8 2 1 0 2 7 8 2 0 0		485887.053	485886.92581	0.12719	
2 8 8 2 0 0 2 7 8 1 9 0		485888.389	485888.24809	0.14091	
12 4 9 111 3 9 0		486496.794	486496.93786	-0.14386	
2 3 3 2 1 0 2 2 2 2 1 1		487539.928	487540.08011	-0.15211	
2 8 5 2 4 1 2 7 5 2 3 1		487605.061	487604.51159	0.54941	
2 3 8 1 5 1 2 3 7 1 7 0		487806.038	487805.54467	0.49333	
2 4 2 2 2 0 2 3 1 2 2 1		488422.634	488421.42965	1.20435	
2 2 8 1 5 1 2 2 7 1 5 0		488445.944	488446.06037	-0.11637	
22 8 14 1 2 2 7 1 6 0		488448.501	488448.66640	-0.16540	
2 1 8 1 4 1 2 1 7 1 4 0		489032.446	489032.85374	-0.40774	
2 1 8 1 3 1 2 1 7 1 5 0		489033.939	489034.20869	-0.26969	
2 0 8 1 3 1 2 0 7 1 3 0		489565.413	489565.48677	-0.07377	
20 8 12 1 2 0 7 1 4 0		489565.413	489566.16734	-0.75434	
1 5 2 1 4 1 1 4 1 1 4 0		489865.735	489865.67886	0.05614	

TABLE I - *Continued*

J'Ka'Kc'TS'	J"Ka"Kc"TS"	Obs. Freq. (MHz)	Calc. Freq. (MHz)	Obs-Calc (MHz)	Ref.
6 6 0 1 5 5 0 0	490035.305	490035.34982	-0.04482		
6 6 1 1 5 5 1 0	490035.305	490035.35000	-0.04500		
19 812 1 19 7 12 0	490047.783	490048.03189	-0.24889		
1 9 8 1 1 1 9 7 1 3 0	490047.783	490048.36087	-0.57787		
2 1 5 1 7 0 2 0 4 1 7 1	490449.1.29	490447.79982	1.32918		
1 8 8 1 1 1 8 7 1 1 0	490484.018	490484.26533	-0.24733		
18 810 1 18 7 12 0	490484.018	490484.41769	-0.39969		
30 1 30 029 1 29 0	490646.946	490646.74852	0.19748		
30 0 30 029 0 29 0	490653.580	490651.58662	1.99338		
30 1 30 129 1 29 1	490715.067	490715.30627	-0.23927		
30 0 30 1 29 0 29 1	490720.272	490720.49364	-0.22164		
28 5 23 1 27 5 22 1	490861.445	490860.71406	0.73094		
1.7 810 1 17 7 10 0	490877.567	490877.70358	-0.13658		
17 8 9 117 7 11 0	490877.567	490877.77082	-0.20382		
16 8 9 116 7 9 0	491231.615	491231.62924	-0.01424		
16 8 8 116 7 10 0	491231.615	491231.65733	-0.04233		
2 8 5 2 3 0 2 7 5 2 2 0	4913)8.157	491316.13133	2.02567		
15 8 8 115 7 8 0	491549.262	491549.10932	0.15268		
15 8 7 115 7 9 0	491549.262	491549.12034	0.14166		
14 8 7 114 7 7 0	491833.223	491833.00825	0.21475		
14 8 6 114 7 8 0	491833.223	491833.01226	0.21074		
13 8 6 113 7 6 0	492086.288	492085.99698	0.29102		
1.3 8 5 113 7 7 0	492086.288	492085.99832	0.28968		
12 8 5 112 7 5 0	4923)0.892	492310.55949	0.33251		
12 8 4 112 7 6 0	492310.892	492310.55989	0.33211		
1 7 2 1 5 1 1 6 1 1 5 0	492331.046	492331.28060	-0.23460		
2 3 4 2 0 0 2 2 3 2 0 1	492495.920	492496.35994	-0.43994		
11 8 4 111 7 4 0	492509.317	492508.99717	0.31983		
11 8 3 111 7 5 0	492509.317	492508.99728	0.31972		
10 8 3 110 7 3 0	492683.686	492683.43196	0.25404		
10 8 2 1107 4 0	492683.686	492683.43199	0.25401		
9 8 1 1 9 7 3 0	492835.977	492835.80827	0.16873		
9 8 2 1 9 7 2 0	492835.977	492835.80827	0.16873		
8 8 0 1 8 7 2 0	492967.977	492967.89416	0.08284		
8 8 1 1 8 7 1 0	492967.977	492967.89416	0.08284		
2 8 3 2 5 0 2 7 3 2 4 0	494503.358	494505.00976	-1.65176		
2 8 3 2 5 1 2 7 3 2 4 1	494889.750	494890.25198	-0.50198		
29 3 27 1 2 8 3 2 6 1	495338.809	495338.87295	-0.06395		
2 8 4 2 4 1 2 7 4 2 3 1	496897.035	496896.50872	0.52628		
2 8 4 2 4 0 2 7 4 2 3 0	497024.387	497025.26238	-0.87538		
29 2 27 1 2 8 2 2 6 1	498060.069	498059.88691	0.18209		
2 3 1 2 2 0 2 2 0 2 2 1	498221.689	498221.69476	-0.00576		
1 6 1 1 5 1 1 5 0 1 5 0	498488.937	498488.91007	0.02693		
22 5 17 0 2 1 4 1 7 1	499244.849	499244.06371	0.78529		
13 4 9 112 3 9 0	499974.060	499974.32291	-0.26291		
1 7 3 1 4 1 1 6 2 1 4 0	500220.668	500220.17858	0.48942		
15 3 1 3 1 1 4 2 1 3 0	500459.629	500459.84050	-0.21150		
3 0 2 2 9 0 2 9 2 2 8 0	501282.958	501283.76612	-0.80812		

TABLE I - *Continued*

J'Ka'Kc'TS'	J"Ka"Kc"TS"	Obs.	Freq. (MHz)	Calc. Freq. (MHz)	Obs-Calc (MHz)	Ref.
3 0 2 2 9 1 2 9 2 2 8 1		501386.273	501386.40949	-0.13649		
30 1 29 1 29 1 28 1		501565.250	501565.10134	0.14866		
23 2 22 022 1 22 1		501716.809	501717.01364	-0.20464		
16 7 9 015 6 9 1		501838.875	501838.39602	0.47898		
16 7 10 015 6 10 1		501838.875	501839.04984	-0.17484		
29 4 26 1 28 4 25 1		502895.550	502896.07359	-0.52359		
13 4 10 1 12 310 0		503823.679	503823.77356	-0.09456		

TS represents the torsional]. substate:0= *gauche+* and 1 = *gauche-*.

* Strongly mixed transition.

a See reference (3); uncertainty is estimated to be better than 100 kHz.

b unpublished transition measured by E. Cohen in 1979 (private communication, 1995) with 200 kHz uncertainty.

c Unpublished assignment by E. Cohen in 1979 (private communication, 1995) and remeasured by this work.

TABLE II

Measured *Gauche*-Ethanol Transitions Not Included in the Analysis.

$J'K_a'K_c'TS'$	$J''K_a''K_c''TS''$	Ohs.	Frequency (MHz)
3 0 1 3 0 1 3 0 0 3 0 0			97877.456
17 9 8 0 16 9 7 0			294456.136
17 9 9 0 16 9 8 0			294456.136
1 8 9 9 0 1 7 9 8 0			311801.488
1 8 9 1 0 0 1 7 9 9 0			311801.488
9 9 0 0 9 8 2 1			321435.654
9 9 1 0 9 8 1 1			321435.654
10 9 1 0 10 8 3 1			321576.180
10 9 2 0 10 8 2 1			321576.180
11 9 2 0 11 8 4 1			321726.427
11 9 3 0 11 8 3 1			321726.427
1 2 9 3 0 1 2 8 5 1			321885.258
12 9 4 0 12 8 4 1			321885.258
13 9 4 0 13 8 6 1			322051.339
1 3 9 5 0 1 3 8 5 1			322051.339
14 9 5 0 14 8 7 1			322223.142
1 4 9 6 0 1 4 8 6 1			322223.142
15 9 6 0 15 8 8 1			322399.224
15 9 7 0 15 8 7 1			322399.224
16 9 7 0 16 8 9 1			322577.893
16 9 8 0 16 8 8 1			322577.893
17 9 8 0 1 7 8 1 0 1			322757.461
17 9 9 0 17 8 9 1			322757.461
1 8 9 9 0 1 8 8 1 1 1			322936.026
1 8 9 1 0 0 1 8 8 1 0 1			322936.026
1 9 9 1 0 0 1 9 8 1 2 1			323111.800
1 9 9 1 1 0 1 9 8 1 1 1			323111.800
2 0 9 1 1 0 2 0 8 1 3 1			323282.766
2 0 9 1 . 2 0 2 0 8 1 2 1			323282.766
2 2 1 2 1 0 1 2 1 1 2 9 1			380588.441
2 2 1 2 1 1 1 2 1 1 2 1 0 1			380588.441
2 2 1 1 1 1 1 2 1 1 1 1 0 1			380642.430
2 2 1 1 1 2 1 2 1 1 1 1 1 1			380642.430
2 2 1 0 1 2 1 2 1 1 0 1 1 1			380740.190
2 2 1 0 1 3 1 2 1 1 0 1 2 1			380740.190
2 2 1 0 1 2 0 2 1 1 0 1 1 0			381110.544
2 2 1 0 1 3 0 2 1 1 0 1 2 0			381110.544
2 2 9 1 3 0 2 1 9 1 2 0			381229.185
2 2 9 1 4 0 2 1 9 1 3 0			381229.185
2 2 6 1 7 0 2 1 6 1 6 0			382103.581
2 2 6 1 6 0 2 1 6 1 5 0			382134.380
23 10 13 1 22 1.0 12 1			398073.626
2 3 1 0 1 4 1 2 2 1 0 1 3 1			398073.626
23 10 13 0 22 1.0 12 0			398458.067
23 10 14 0 22 1.0 13 0			398458.067

TABLE I - *Continued*

J'	K_a'	K_c'	TS'	J''	K_a''	K_c''	TS''	Obs.	Frequency (MHz)					
2	3	9	1	4	0	2	2	9	1	3	0	398599.923		
2	3	9	1	5	0	2	2	9	1	4	0	398599.923		
2	3	6	1	8	0	2	2	6	1	7	0	399605.475		
2	3	6	1	7	0	2	2	6	1	6	0	399655.490		
2	4	3	0	1	4	1	2	3	1	0	1	3	1	415412.599
2	4	1	0	1	5	1	2	3	1	0	1	4	1	415412.599
24	3	22		1	2	3	3	2	1	1		415423.060		
2	4	9	1	5	1	2	3	9	1	4	1	415577.975		
24	9	1	6	1	2	3	9	1	5	1		415577.975		
2	4	1	0	1	4	0	2	3	1	0	1	3	0	415808.789
24	10	15	0	23		1.0	14	0				415808.789		
2	4	9	1	5	0	2	3	9	1	4	0	415977.816		
2	4	9	1	6	0	2	3	9	1	5	0	415977.816		
2	4	6	1	9	1	2	3	6	1	8	1	416861.497		
2	4	6	1	8	1	2	3	6	1	7	1	416935.101		
2	4	6	1	9	0	2	3	6	1	8	0	417123.040		
2	4	6	1	8	0	2	3	6	1	7	0	417202.363		
2	4	3	2	1	0	2	3	3	2	0	0	423079.517		
2	4	4	2	0	1	2	3	4	1	9	1	423274.366		
9	8	1	0	8	7	1	1					428471.075		
9	8	2	0	8	7	2	1					428471.075		
27	7	21		1	2	7	6	2	1	0		428729.620		
2	7	7	2	0	1	2	7	6	2	2	0	429559.300		
2	6	7	2	0	1	2	6	6	2	0	0	430133.525		
2	6	7	1	9	1	2	6	6	2	1	.	0	430669.083	
25	7	19		1	2	5	6	1	9	0		431364.328		
2	5	7	1	8	1	2	5	6	2	0	0		431703.299	
11	8	3		0	1	0	7	3	1			463341.035		
11	8	4		0	1	0	7	4	1			463341.035		
27	2	2	5	0	2	6	2	2	4	0		466125.629		
2	7	8	1	9	1	2	6	8	1	8	1		468061.740	
2	7	8	2	0	1	2	6	8	1	9	1		468061.740	
2	7	8	1	9	0	2	6	8	1	8	0		468448.423	
2	7	8	2	0	0	2	6	8	1	9	0		468448.423	
2	7	7	2	1	1	2	6	7	2	0	1		468635.735	
2	7	7	2	1	0	2	6	7	2	0	0		468975.324	
2	7	7	2	0	0	2	6	7	1	9	0		468992.875	
27	6	22		126		6.21		1				469475.128		
2	7	6	2	1	1	2	6	6	2	0	1		469733.706	
27	6	2	2	0	2	6	6	2	1	0		469761.882		
2	7	6	2	1	0	2	6	6	2	0	0		470039.687	
2	7	5	2	3	0	2	6	5	2	2	0		470376.556	
9	9	0	0	8	8	0	1					477122.246		
9	9	1	0	8	8	1	1					477122.246		
12	8	4		0	1	1	7	4	1			480789.559		
12	8	5		0	1	1	7	5	1			480789.559		
28	8	21		1	27		8	2	0	1		485486.465		
2	8	8	2	0	1	2	7	8	1	9	1		485487.725	
28	7	22		1	27		7	21	1			486127.288		

TABLE II - *Continued*

J'Ka'Kc'TS'	J"Ka"Kc"TS"	Obs.	Frequency (MHz)
28 7 21	1 2 7 7 2 0 1		486153 .20"1
2 8 7 2 2	0 2 7 7 2 1 0		486478.638
2 8 7 2 1 0	2 7 7 2 0 0		486506.646
2 8 6 2 3 1	2 7 6 2 2 1		487039.802
24 8 17	1 2 4 7 1 7 0		487093.325
2 4 8 1 6 1	2 4 7 1 8 0		487103.104
2 8 6 2 3 0	2 7 6 2 2 0		487331.192
1 8 6 1 2 0	1 7 5 1 2 1		487363.080
2 8 6 2 2 1	2 7 6 2 1 1		487417 ."/13
1 8 6 1 3 0	1 7 5 1 3 1		487461.494
2 8 6 2 2 0	2 7 6 2 1 0		487737.133
2 3 8 1 6 1	2 3 7 1 6 0		487801.166
2 8 5 2 4 0	2 7 5 2 3 0		487846.044
1 0 9 1 0	9 8 1 1		494572.145
1 0 9 2 0	9 8 2 1		494572.145
2 9 3 2 7 0	2 8 3 2 6 0		495195.368
2 9 2 2 7 0	2 8 2 2 6 0		497730.845
13 8 5 012	7 5 1		498245.245
13 8 6 012	7 6 1		498245.245
3 0 1 2 9 0	2 9 1 2 8 0		501454.524
2 9 8 2 2 1	2 8 8 2 1 1		502921.625
29 8 21	1 2 8 8 2 0 1		502923.735
2 9 8 2 2 0	2 8 8 2 1 0		503336.069
2 9 8 2 1 0	2 8 8 2 0 0		503338.342
2 9 7 2 3 1	2 8 7 2 2 1		503633.146
29 7 22	1 2 8 7 2 1 1		503673.755
2 9 7 2 3 0	2 8 7 2 2 0		503995.924
29 7 22	0 2 8 7 2 1 0		504039.739

TS designates the torsional substate: 0=gauche+, l=gauche-

TABLE 111

Derived *Gauche* Rotational and Interaction Constants^{a,b}

Constant	Value (MHz)	1σ Uncertainty
A^+	34194.6748	0.0065
B^+	9189.09754	0.00099
C^+	8099.37146	0.00111
$-\Delta_J^+ \times 10^3$	-8.87076	0.00067
$-\Delta_{JK}^+ \times 10^3$	187.354	0.239
$-A_k^+ \times 10^3$	-291.50	1.25
$d_1^+ \times 10^3$	-1.57807	0.00038
$d_2^+ \times 10^3$	0.222711	0.000153
$H_J^+ \times 10^7$	1.3539	0.0057
$H_{JK}^+ \times 10^7$	-90.282	0.616
$H_{KK}^+ \times 10^3$	-0.23451	0.00093
$H_K^+ \times 10^3$	-0.41214	0.00285
$h_1^+ \times 10^7$	0.026750	0.00377
$h_2^+ \times 10^7$	-0.63659	0.00297
$h_3^+ \times 10^7$	-0.08362	0.00131
F^+	0.0	(fixed) "
ΛE^+	0.0	(fixed) '
A^-	34199.269	0.051
B^-	9200.371	0.051
C^-	8100.15397	0.00113
$-\Delta_J^- \times 10^3$	-8.60514	0.00067
$-\Delta_{Am}^- \times 10^3$	-115.575	0.180
$-\Delta_K^- \times 10^3$	-256.64	1.17
$d_1^- \times 10^3$	-2.02237	0.00040
$d_2^- \times 10^3$	-0.345718	0.000204
$H_J^- \times 10^7$	-0.33656	0.00525
$H_{JK}^- \times 10^7$	112.47	0.60
$H_{KK}^- \times 10^3$	0.18208	0.00075
$H_K^- \times 10^3$	0.59336	0.00217
$h_1^- \times 10^7$	0.23791	0.00344
$h_2^- \times 10^7$	0.60007	0.00236
$h_3^- \times 10^7$	0.11924	0.00112
F^-	374.84	1.71
ΛE^-	96748.8164	0.0069
E^{+-}	119.942	0.121

TABLE 111 - *Continued*

Constant	Value (MHz)	1σ Uncertainty
D ⁺⁻	-17.9201	0.0141
N +	88.502	0.100
Q +	-4054.965	0.077
QK+	11.2388	0.0195
N~+-	-21.929	0.052
Q _J +-	-1.6283	0.0083
N _J +-	-0.093354	0.000177
N _{KK} +-	0.047372	0.000193
Q _{JJ} +- x 10 ⁶	-6.835	0.904
N _{JJ} +- x 10 ⁶	1.530	0.064
Q _{JK} +- x 10 ³	-3.0302	0.0140
N _{JK} +- x 10 ³	2.7696	0.0074

a_{D,E,ΔE,F,N}, and q are defined in Section II.

b - is gauche-, + is gauche+, and +- is the interaction between gauche+ and gauche-

c See text

TABLE IV

Approximate Maximum J values for Separate Analyses of *Trans* and
Gauche Substates

	<i>Trans</i> Limits	<i>Gauche+</i> Limits	<i>Gauche-</i> Limits
$K_a = 0$	33+	30	29
$K_a = 1$	32	29	27
$K_a = 2$	30	21	21
$K_a = 3$	29	25	28
$K_a = 4$	28	27	21
$K_a = 5$	26	25	26
$K_a = 6$	24	24	18
$K_a = 7$	21	24*	24
$K_a = 8$	18	18*	18*
$K_a = 9$	15	15*	15*
$K_a = 10$	11	11*	11*

* c-type *Gauche+* to *Gauche-* transitions cannot be fit to microwave accuracy,

Figure Captions

Figure 1. The potential energy for the OH torsional motion as determined by Kakar and Quade (?) plotted vs torsional angle with the *trans* configuration defined to have a torsional angle of 0° . The three wells are the *trans* well (the global minimum) and the two *gauche* wells (the secondary minima).

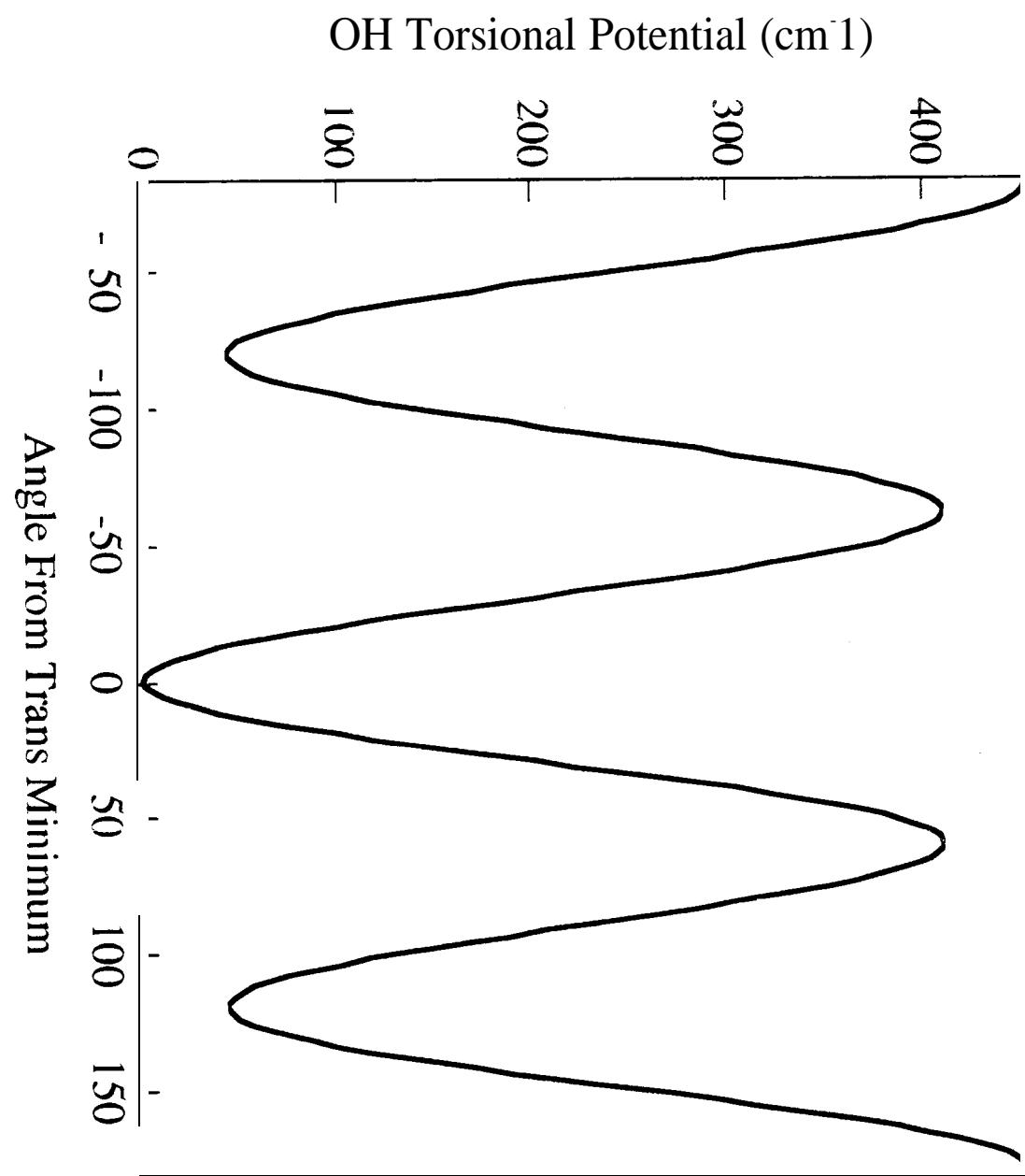
Figure 2. Calculated wave functions from the potential of Kakar and Quade (3) for the three lowest-lying *trans*, *gauche*+ and *gauche*- substates, respectively. Although the wave functions are fairly well localized, there will be interactions among the three substates.

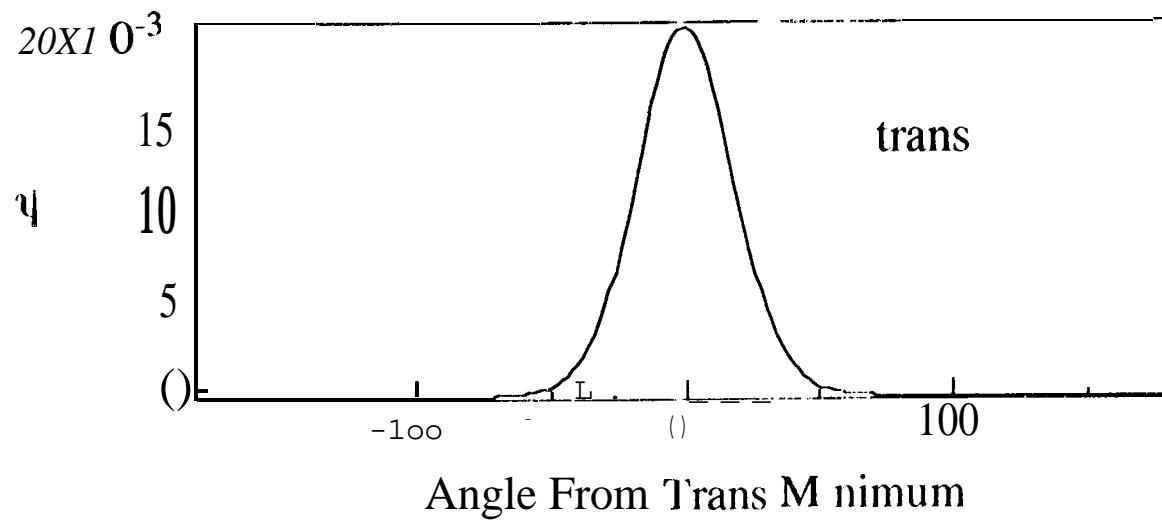
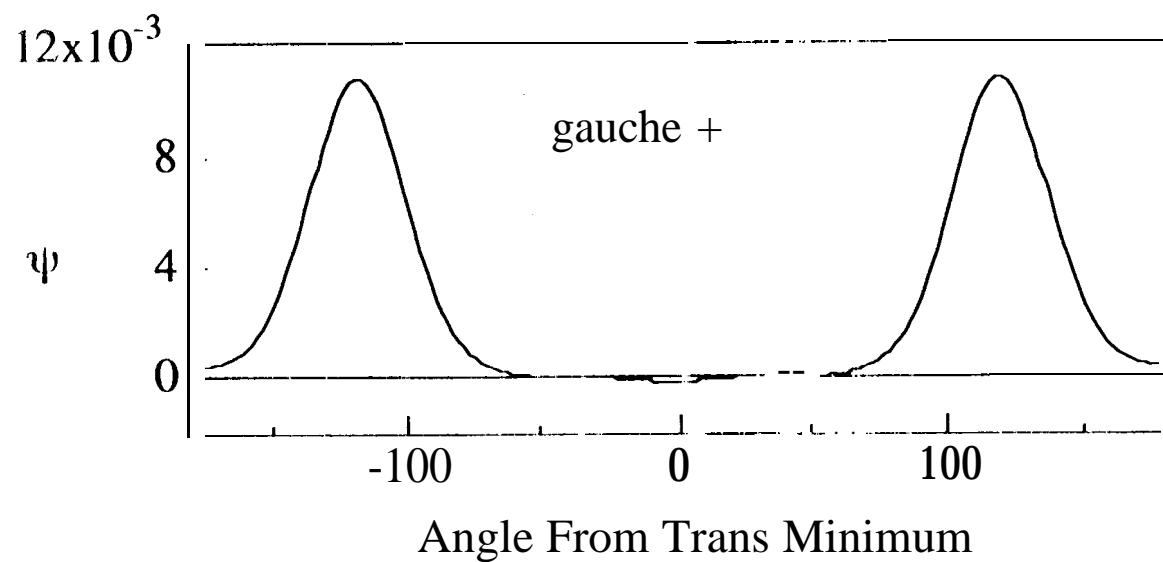
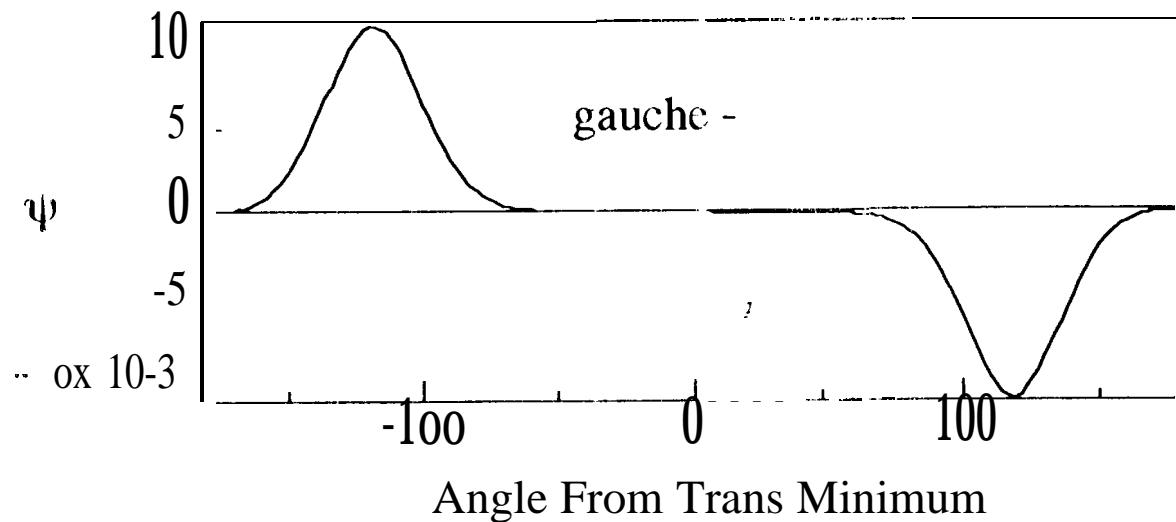
Figure 3. The effects of the two internal motions on a single asymmetric rotor energy level are depicted. The hydroxyl torsion introduces a large effect while the high barrier methyl torsion introduces a small splitting which is only sometimes observable. The hydroxyl splittings listed are from this work.

Figure 4. The symmetry-allowed first order effective Hamiltonian matrix elements are shown. The 2×2 box containing the *gauche*+ and *gauche*- contributions is used in this analysis,

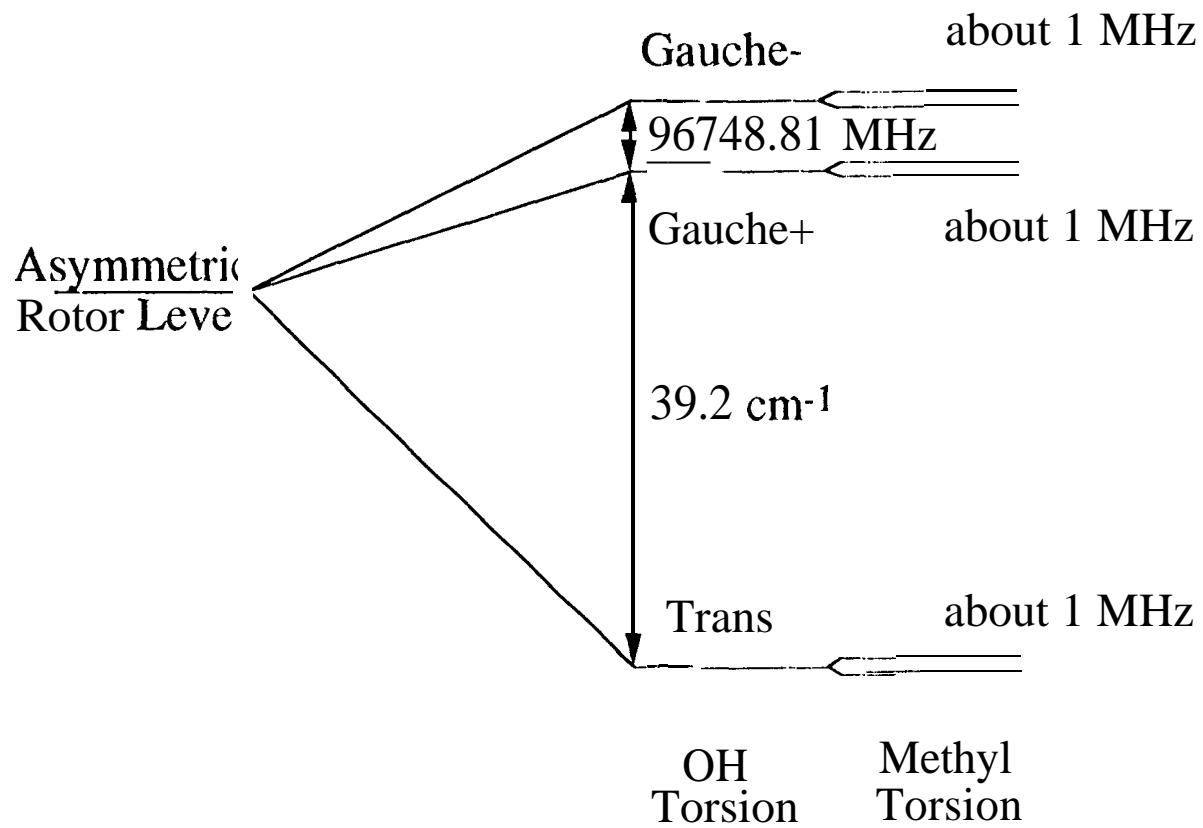
Figure 5. The rotational energy levels of the *trans* and *gauche* substates of ethyl alcohol from this analysis and the one in (1) are plotted vs J. A 39.2 cm^{-1} energy difference between the *trans* and *gauche*+ state has been used, ‘l’he stacks consist of the levels with differing K_a in the three torsional substates. ‘l’he energies shown do not include the effects of *trans-gauche* interactions.

Figure 6. The rotational energy levels with $K_a = 11$ and 12 in the *trans* substate, with $K_a = 9$ in the *gauche*+ substate, and with $K_a = 10$ in the *gauche*- substate are plotted vs. J. The *trans* levels are denoted with + while the *gauche*+ and *gauche*- levels are denoted by o and x respectively. The crossings between $J = 25$ and 30 are apparent.





Ethanol: the Ground OH Torsional State



Symmetry - allowed Hamiltonian Matrix Elements

Trans Rotational Hamiltonian $+P_a P_b + P_b P_a$ $+ \Delta E^t$	P_c $P_a P_b + P_b P_a$	P_a, P_b $P_c P_a + P_a P_c$ $P_b P_c + P_c P_b$
P_c $P_a P_b + P_b P_a$	Gauche+ Rotational Hamiltonian $+P_a P_b + P_b P_a$ $+ \Delta E^+$	P_a, P_b $P_c P_a + P_a P_c$ $P_b P_c + P_c P_b$
P_a, P_b $P_c P_a + P_a P_c$ $P_b P_c + P_c P_b$	P_a, P_b $P_c P_a + P_a P_c$ $P_b P_c + P_c P_b$	Gauche- Rotational Hamiltonian $+P_a P_b + P_b P_a$ $-t \Delta E^-$

